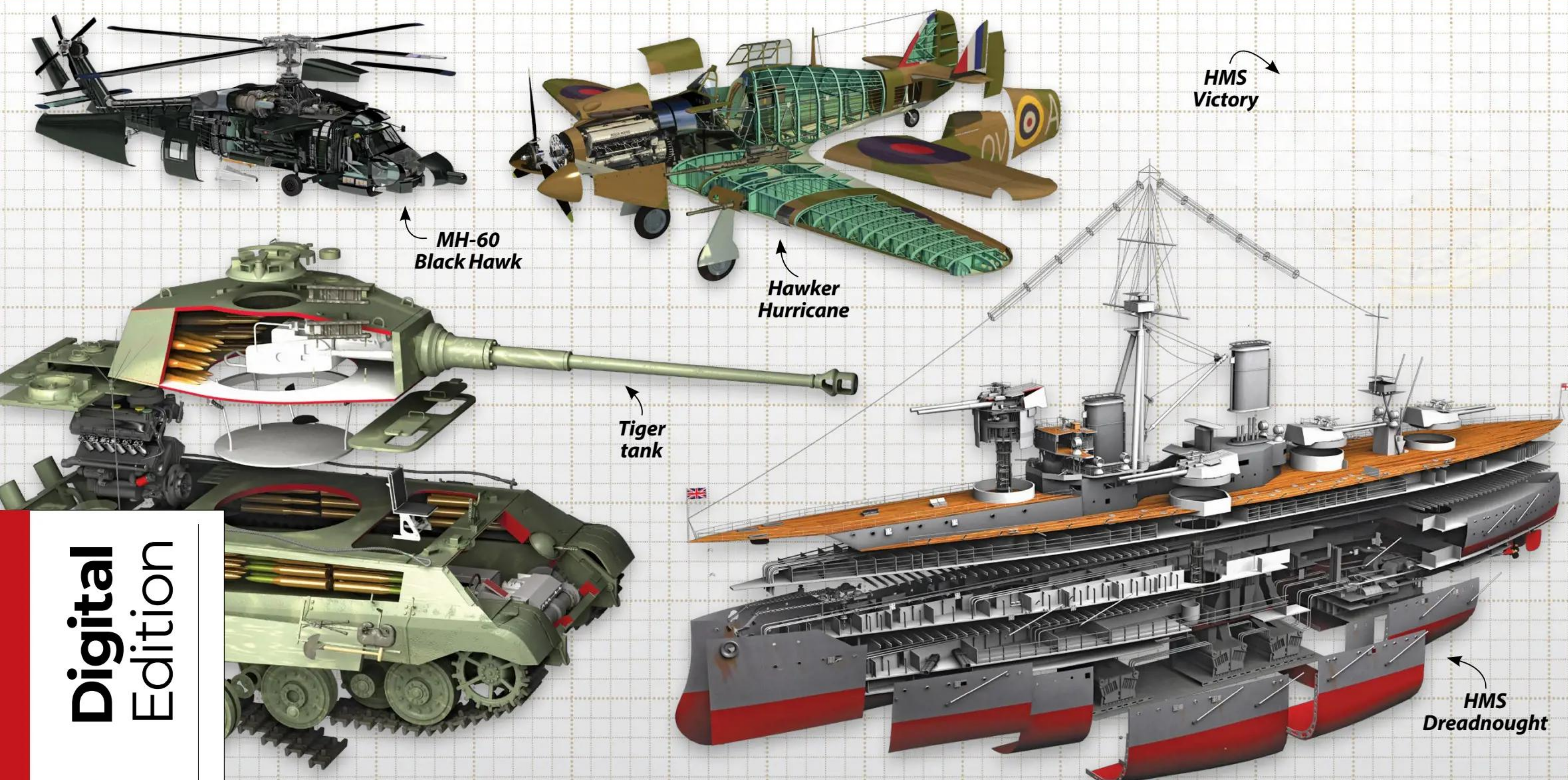




MILITARY CUTAWAYS

★ INSIDE THE ENGINEERING OF HISTORY'S GREATEST TANKS, FIGHTER PLANES, WARSHIPS & MORE ★



Digital
Edition



FIRST
EDITION

★ FIRST WORLD WAR ★ WWII ★ MEDIEVAL ★ COLD WAR ★ 21ST CENTURY



62 KK 69 



WELCOME

Beyond the brutal realities of the battlefield, military history is a story of human invention and innovation. Engineers across the eras have been at the forefront of the race to create more powerful, faster and deadlier tools to seize the tactical edge. In the 21st Century, that race has only accelerated. Today's combat technology stands on the shoulders of giants, refining centuries of hard-fought lessons from the front lines. From ships that ruled the ancient seas, to fighter jets that reigned supreme in the skies of the 20th Century, this book puts you into the cockpit, the driver's seat and inside the engine rooms of machines that have changed not just warfare, but world history forever.

CONTENTS

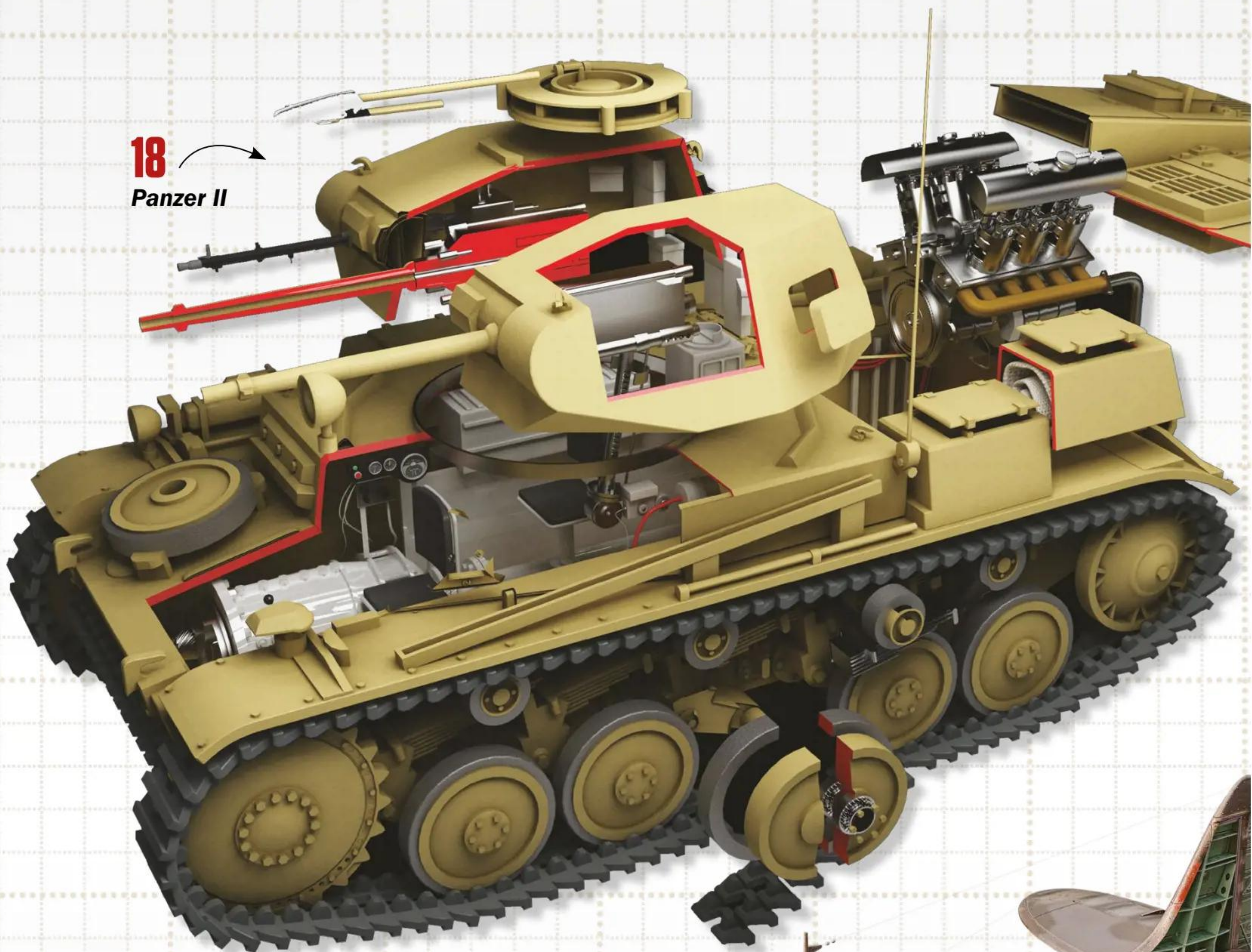


44
Caernarfon
Castle

LAND

- 6** MARK IV TANK
- 10** STURMPANZERWAGEN A7V
- 12** MEDIUM MARK A WHIPPET
- 14** VICKERS-MAXIM GUN
- 16** FLAMETHROWERS
- 18** PANZER II
- 20** MATILDA II
- 22** STEN GUN
- 24** PANZER V 'PANTHER'
- 26** KING TIGER
- 30** CENTURION MBT
- 32** M1 ABRAMS MBT
- 36** HUMVEE
- 38** CHALLENGER 2
- 40** T-72 MBT
- 42** CAERNARFON CASTLE
- 46** HIMEJI CASTLE

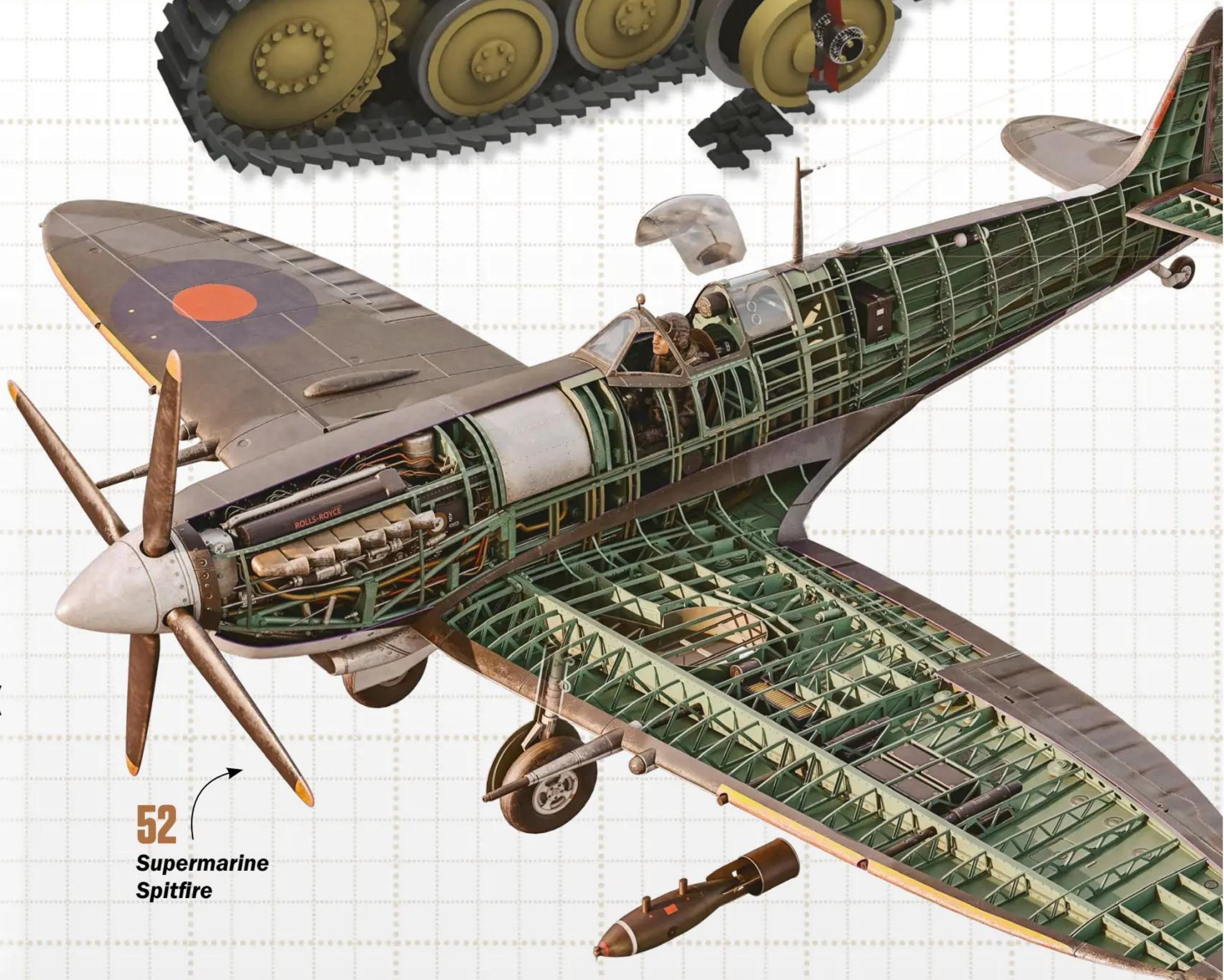
18
Panzer II



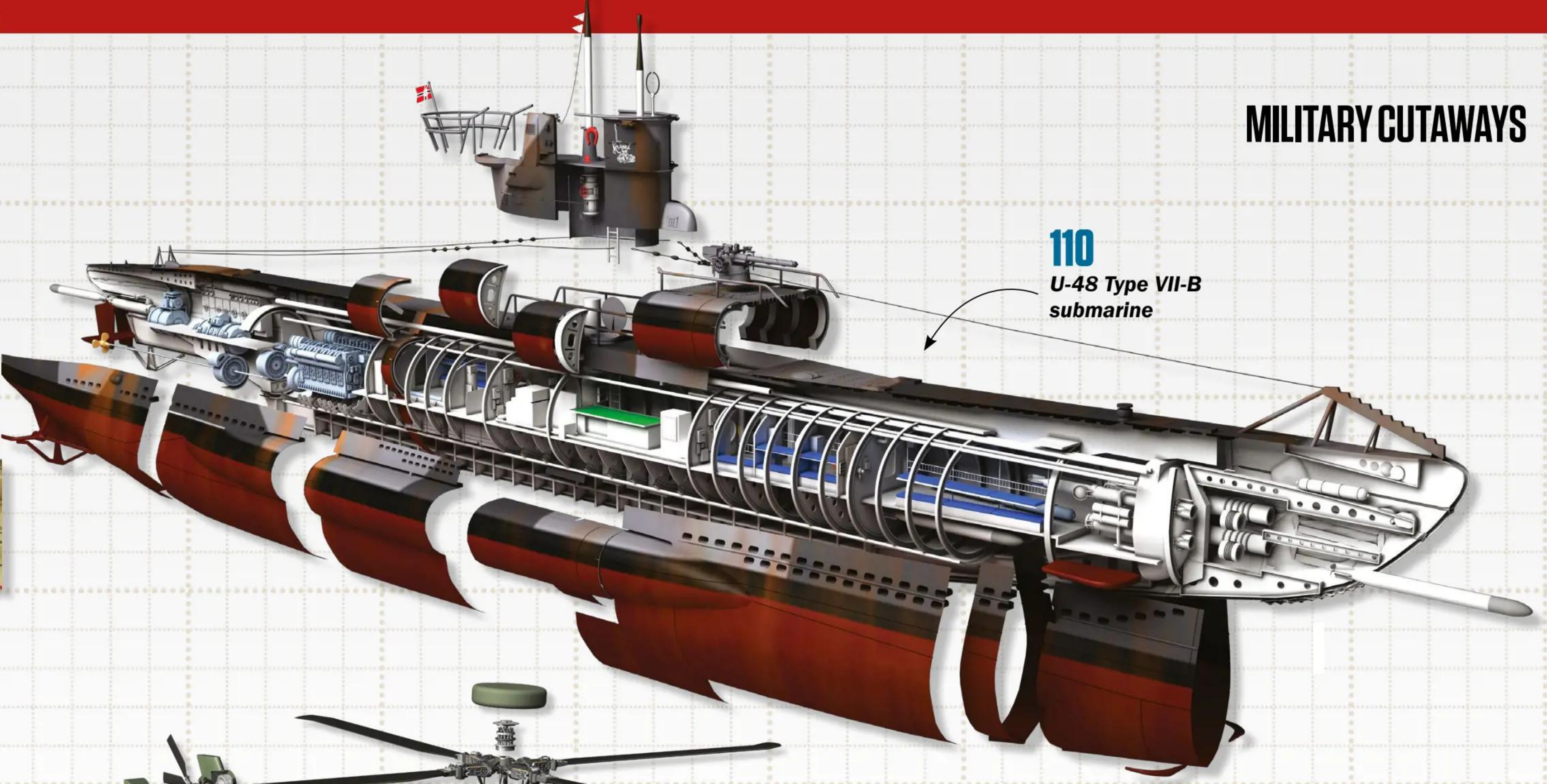
AIR

- 48** FOKKER EINDECKER
- 50** VICKERS VIMY
- 52** SUPERMARINE SPITFIRE
- 54** MITSUBISHI A6 M 'ZERO'
- 56** HAWKER HURRICANE
- 58** V-2 ROCKET
- 62** MESSERSCHMITT ME 262
- 64** S.L.A.M. MISSILE
- 66** F-16 FIGHTING FALCON
- 68** LOCKHEED U-2
- 70** MiG-15
- 72** AVRO VULCAN
- 74** SIKORSKY MH-60 BLACK HAWK
- 76** TOMAHAWK MISSILE
- 78** A-10 WARTHOG
- 80** AH-64D APACHE
- 82** F-35 LIGHTNING
- 84** TEMPEST
- 86** ANTI-DRONE GUN

52
Supermarine
Spitfire



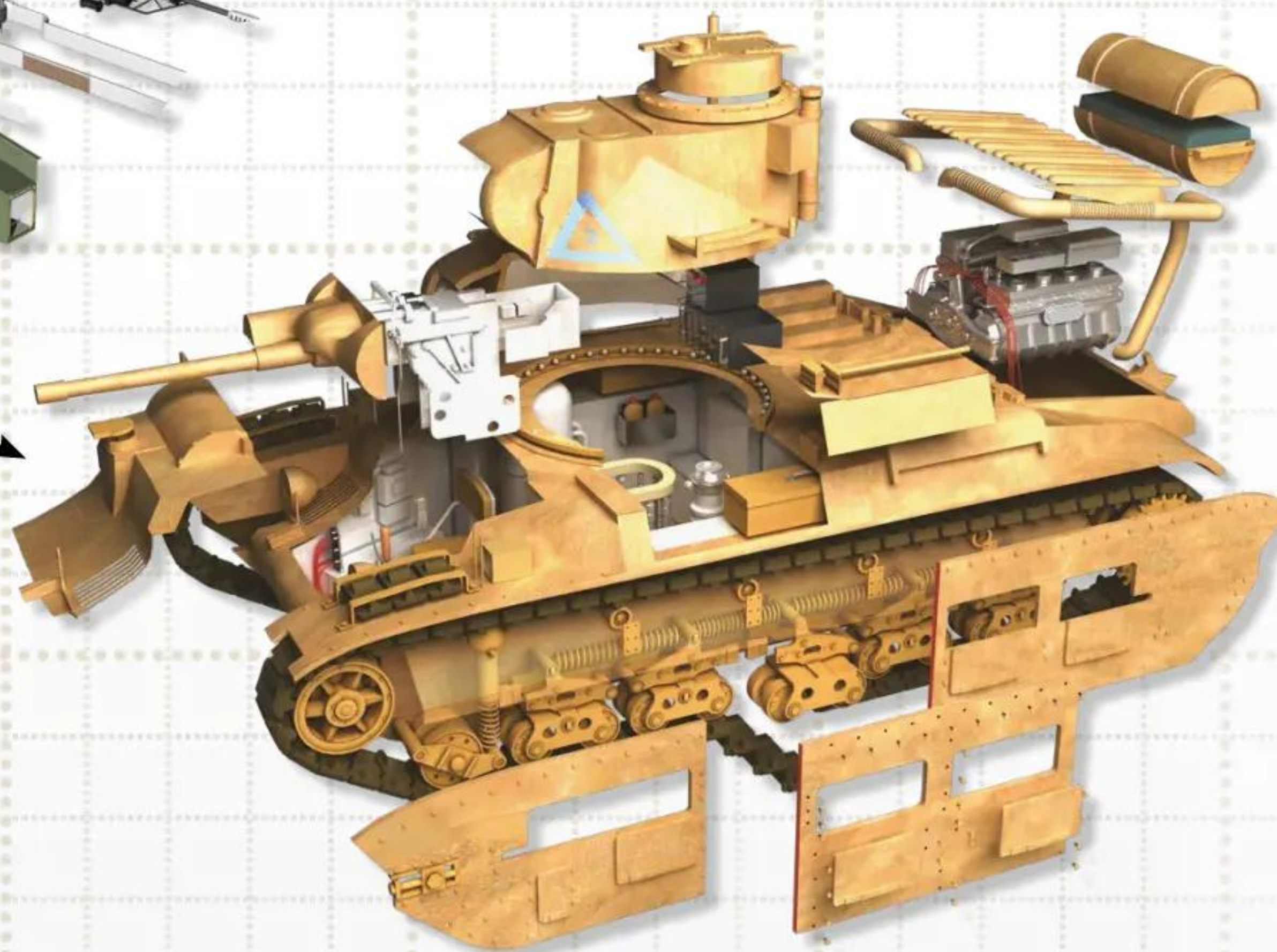
MILITARY CUTAWAYS



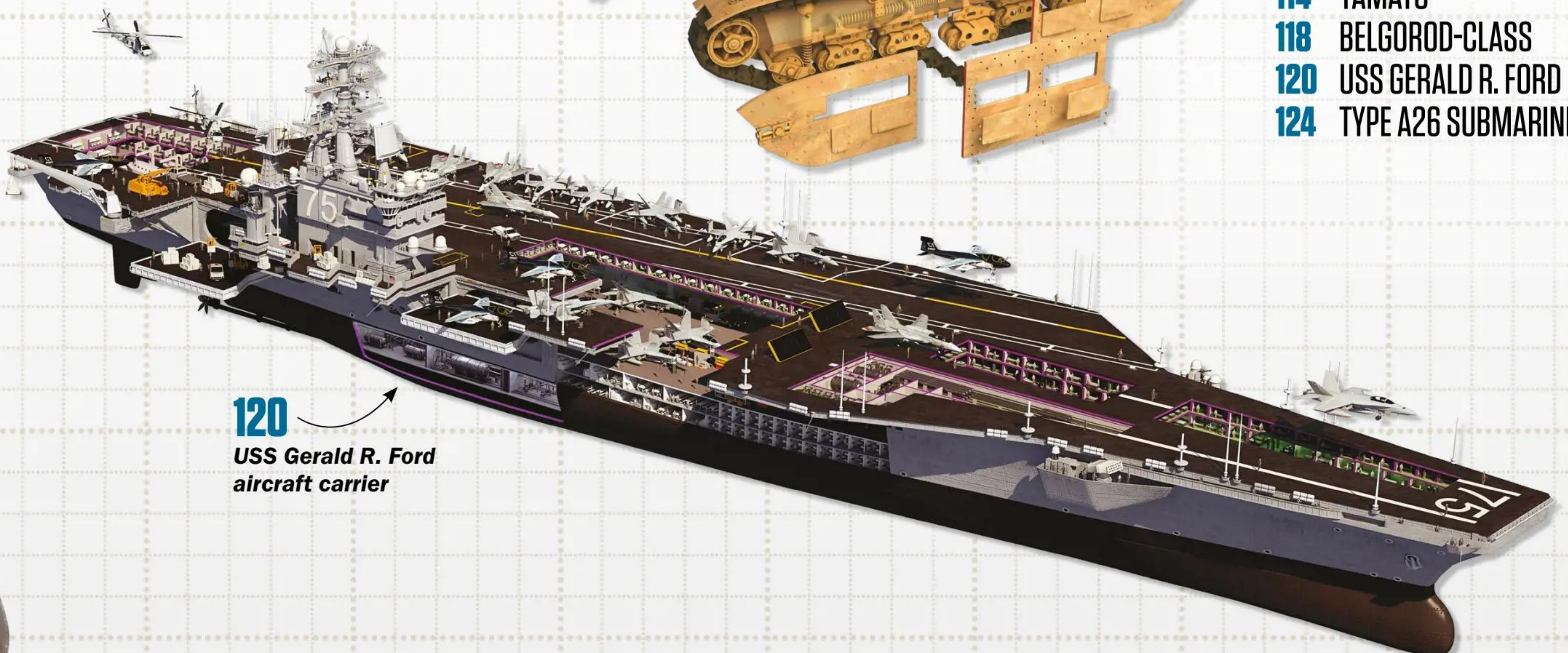
110
U-48 Type VII-B
submarine



80
AH-64D
Apache
gunship



20
Matilda II
tank



120
USS Gerald R. Ford
aircraft carrier

SEA

- 88** ROMAN WARSHIP
- 90** THE MARY ROSE
- 92** PORTUGUESE NAU
- 94** HMS VICTORY
- 98** USS MONITOR
- 100** CSS HUNLEY
- 102** HMS DREADNOUGHT
- 106** SUPERMARINE S.6B
- 108** IJN AKAGI
- 110** U-48 TYPE VII-B
- 114** YAMATO
- 118** BELGOROD-CLASS
- 120** USS GERALD R. FORD
- 124** TYPE A26 SUBMARINE



DAWN OF THE TANK AGE

In 1917 the British Army launched its latest, though as-yet unproven, battlefield technology, in a bid to break the static face-off on the Western Front. Was it the overwhelming success generals had hoped for?

At 6am on 20 November 1917 the men of 84 Infanterie-Regiment were slumbering in their dugouts, secure in the knowledge that they occupied the most formidable German positions on the entire Western Front. It was a sector so quiet that troops called it the 'silent front' or the 'Flanders sanatorium', where divisions were sent to recover from the slaughter in the Ypres Salient.

In such a peaceful place it should have been impossible for the enemy to conceal any preparations for an attack. Yet at 6.20am the calm was shattered by a stupendous artillery bombardment that erupted without warning on the German lines. Leutnant Adolf Saucke raced to the entrance of his dugout. "In the dawn, the trench was like a sea of fire from the ceaseless detonation of falling shells," he later described. When the barrage moved forward, they rushed out to man the trenches but could see nothing: "In front of us, No-Man's Land was cloaked in grey morning mist. Behind us lay a greyish-yellow wall of fog, from which emerged dazzling flashes of flame from the constantly bursting shells."

Ahead in No-Man's Land lay a network of advanced outposts designed to detect and disrupt an attack. Peering into the mist from one of these positions, Leutnant Adolf Mestwarb heard an astonished cry: "Sir, something square is coming!" As it lumbered forward, Mestwarb recognised the angular form of a British tank but with an enormous object perched on its roof. "We immediately opened fire, but unfortunately without making the slightest impression on the brute. It moved further forward, firing as it went, then veered to the left to make room for those behind, which were now appearing one after another from behind the wood in front of us."

As they were driven back by fire from the tanks and from low-flying aircraft, Leutnant Mestwarb had no idea that the same story was being repeated along six miles of the German front. A total of 378 fighting tanks, supported by six divisions of infantry, were surging forwards, preceded by a hurricane of artillery fire. Each tank bore an enormous bundle of brushwood known as a 'fascine' to drop into the German trenches as a kind of stepping-stone, allowing itself and others to cross. Astonishing as it seems, all these tanks and infantry had been secretly moved into position, along with 1,000 field guns and the entire Cavalry Corps, ready to exploit a breakthrough, without the Germans having any idea of the scale of the offensive that was about to burst upon them.

Most astonishing of all, the attack was being launched not against some weak point in the German defences but against a massive and seemingly impregnable trench system known to the British as the Hindenburg Line and to the Germans as the Siegfriedstellung. The name was highly symbolic, because Siegfried was the greatest hero of Norse mythology – a young man who did not know the meaning of fear.

It was the start of the Battle of Cambrai, perhaps the most extraordinary operation of World War I and one that would ultimately change the conduct of warfare forever. Despite weeks of planning and preparation, the attack was a journey into the unknown for the crewmen sealed inside their 28-ton machines, as they lumbered across No-Man's Land at four miles per hour (6 kilometres per hour).

They had no idea if their tanks could penetrate the dense belts of barbed wire and crush a path that the infantry would be able to follow, no idea if their fascines would bridge the gulf of the German trenches and no idea

H45 Hyacinth, ditched near the village of Ribécourt on 20 November, dramatically illustrates the hazards of crossing the wide German trenches



First World War

MARK IV TANK

Hundreds of Britain's latest tank design were deployed at the Battle of Cambrai

CREW COMPARTMENT

The eight-man crew consisted of a Commander (usually a junior officer); Driver (normally an NCO); four Gunners (in the side sponsons); and two Gearsmen (located at the rear of tank).

SPONSONS

In the Male version of the tank (shown here) a door in rear provided main entry and exit for the crew. The sponsons can slide into the tank body when transported by rail. In 'Female' versions of the tank, the sponsons were narrower, with openings underneath providing main crew entry and exit.

ARMAMENT

'Male' tanks (shown) were loaded with six-pounder 23-calibre Hotchkiss quick-firing (QF) guns, adapted from naval guns but with shorter barrels, firing solid shot, high explosive and case shot. Its effective range was 21,900 feet (6.7km). Also included were three air-cooled drum-fed .303 Lewis guns. 'Female' tanks were fitted with two Lewis guns in each sponson and one at the front.

SPECIFICATIONS

CREW: 8
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1917
RANGE: 35 MILES (56km)
ARMOUR: UP TO 0.5" (12mm)
ENGINE: DAIMLER SIX-CYLINDER
WEAPONS: 2x OF 6-POUNDER HOTCHKISS GUNS (MALE); UP TO 5x LEWIS GUNS

PETROL TANK

70 gallons (318 litres) of fuel capacity with a trundling performance of around 0.5 miles per gallon (0.2 km per litre) gave the Mk. IV a theoretical effective range of 35 miles (56km).

TRACKS

90 steel plates with unsprung suspension

ENGINE

The Daimler 105 horsepower six-cylinder engine was located in the same compartment as the crew, who were exposed to noise, heat and fumes. It had a two-speed and reverse gearbox, with secondary two speed selectors.

if the barrage, fired from unregistered field guns, would destroy its targets – particularly the enemy artillery known to be waiting ahead, which posed the only real threat to the tanks.

One of the machines bearing down on the men of 84 Infanterie-Regiment was D27 Double Dee III, commanded by Second Lieutenant Horace Birks.

"Emerging out of the gloom a dark mass came steadily towards us: the German wire. It appeared absolutely impenetrable... It neither stopped the tank nor broke up and wound round and round with the tracks as we at first feared, but it squashed flat and remained flat, leaving a broad carpet of wire as wide as the tank, over which the following infantry were able to pick their way without great difficulty... It was a relief to get through the wire and come out on to the main German position. All this time there had been no firing and very little shell fire, and the tanks on the right and left could be seen keeping station with us," he recalled later.

So far so good, but they then had their first view of the enormous German trenches, which had been dug up to 3.5 metres wide to act as anti-tank obstacles. Advancing to the right of Birks's tank was E45 Elles II, commanded by Second Lieutenant Fred Dawson. "First, poised over the deep and wide excavation: then, releasing the fascine – would it drop all right? We saw it lumber beautifully into the bottom. But could we get over? One can imagine our doubts... Anyhow, down we dropped and up, up, up – no one thought of the 'balance point' – until at last we crashed upon the other side, splitting open my section commander's head, and petrol cans, oil cans and ammunition boxes scattered all over the place."

Once safely across, the tank crews encountered varying levels of resistance depending on the fighting qualities of the units facing them. A battalion commander in 84 Infanterie-Regiment, Hauptmann Harro Soltau, told his staff, "A Prussian officer does not retreat," and sent a final message to regimental headquarters: "We will hold on till the last man." Other attackers came up against older Landwehr troops and found the biggest challenge was pressing forward as hundreds of men surrendered. But all resistance was swept aside, whether the Germans gave themselves up, or fled, or fought to the death like Soltau and his men.

In his tank D45 Destroyer II, Lieutenant James Macintosh (who referred to himself as 'Tosh') described how men of the 84th scattered from a trench ahead of them: "Then for the crew... began the rabbit-shooting of their fondest dreams. Streams and streams of the enemy, their retreat cut off by Tosh and their front menaced by the approaching wave, broke wildly from cover. As fast as the gunners could reload, they poured in a hail of bullets, Tosh himself firing and yelling like a maniac. At last the panic subsided, the remainder of the enemy apparently realising the futility of an attempt to escape: but it left Tosh and his crew hoarse with joy and almost beside themselves with excitement. To those who have never experienced it, the lust of battle must always appear unnatural and terrible, but ever after Tosh would look back to those few minutes of slaughter as among the most joyful moments of his life."

First World War

STURMPANZERWAGEN

A7V

Germany's first operational tank, the Sturmpanzerwagen A7V made its combat debut during the desperate Spring Offensive in 1918

The only operational German tank of the First World War was the product of a hurried development program. It began with the formation within the War Ministry of the Allgemeines Kriegsdepartement Abteilung 7 Verkehrswesen (which translates as General War Department Section 7, Transportation) in the autumn of 1916. This new department also contributed a part of its name to its first production vehicle, the Sturmpanzerwagen A7V.

Joseph Vollmer, a German army captain and well-known automobile designer, led the team

of engineers that developed the A7V. The tank was essentially an armoured box placed atop the chassis of a Holt tractor.

Its spring suspension was taxed by the vehicle's 32-ton, 24 feet (7.34-metre) long and 10.8 feet (3.3-metre) high body. Armour plating was up to 1 inch (30mm) thick on the front and 0.6 inches (15mm) on each side. Hinged doors allowed crewmen to enter and exit the A7V, while the engine was placed in the centre of the crew compartment, restricting movement. Low ground clearance – no more than 16 inches (140 centimetres) – hampered battlefield mobility.

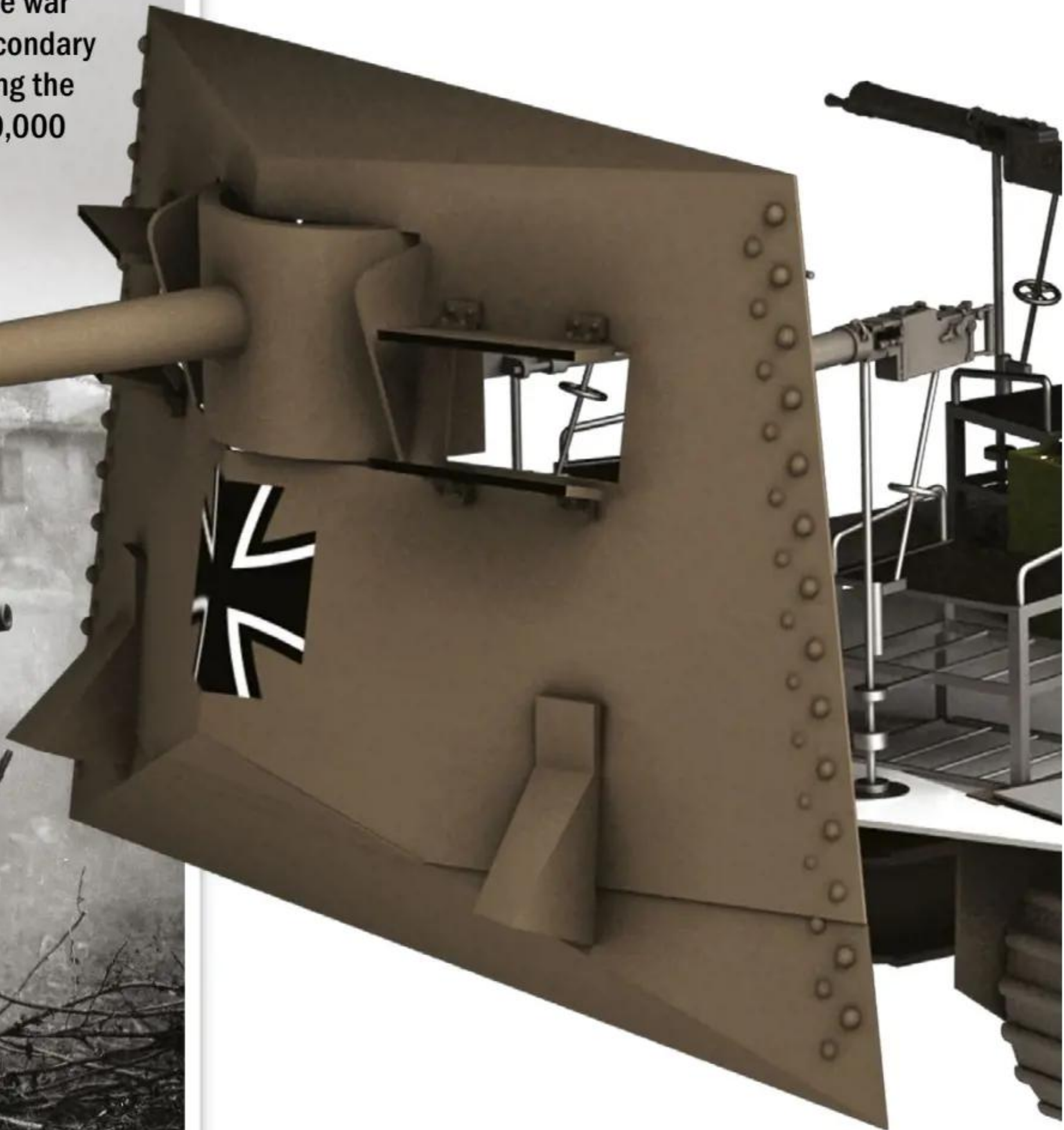


SPECIFICATIONS

- CREW: 18
- COUNTRY OF ORIGIN: GERMANY
- COMMISSIONED: 1918
- RANGE: 50 MILES (80km)
- ARMOUR: UP TO 1" (30mm)
- ENGINE: 2x DAIMLER-BENZ 4-CYLINDER 100-HORSEPOWER PETROL ENGINES
- WEAPONS: 57mm MAXIM-NORDENFELT CANNON; 6x 7.92mm MAXIM MG08

ARMAMENT

The primary weapon of the Sturmpanzerwagen A7V was the 57mm Maxim-Nordenfelt cannon set forward in the centre of the hull, in either a pyramid and pedestal mount called a Sockellafette or a trestle mount called a Bocklafette. These heavy weapons, adapted from field artillery pieces with a range up to 2,950 yards (2,700 metres), were of British, Russian or Belgian manufacture, either procured before the war or captured on the battlefield. 500 rounds were stored inside the A7V. Secondary armament included six 7.92mm Maxim MG08 machine guns mounted along the sides and rear of the hull to engage with enemy infantry. Approximately 30,000 rounds of 7.92mm ammunition was carried.



An A7V named 'Wotan' in active service in 1918

ENGINE

The twin 100-horsepower, four-cylinder Daimler engines mounted aboard the A7V provided a top speed of only nine miles per hour (15 kilometres per hour) on suitable roadways, and just over four miles per hour (six kilometres per hour) traversing open cross-country terrain. The vehicle was significantly underpowered for its substantial weight of 32 tons, hampering performance in the field. The engines were paired with Adler gearboxes and differentials, while thick exhaust was emitted through a system of pipes that ran along the lower sides of the hull. The noise level of the engines complicated communications inside the armoured vehicle, and 110 gallons (500 litres) of fuel was stored aboard the A7V.

ARMOUR

While the roof of the vehicle was relatively weak, with only 6mm plating, the rest of the body was well-reinforced and more than capable of ploughing through rough conditions. The front alone boasted 1-inch (30mm) thick armour.

CREW COMPARTMENT

The interior of the Sturmpanzerwagen A7V was cramped and often filled with noxious exhaust fumes that sickened the crew of 17 soldiers and a single officer – particularly during training exercises or combat when weapons were fired, releasing additional smoke. Two crewmen, a gunner and a loader, were needed to service each weapon. The ponderous tank also required a pair of drivers, positioned in a bridge area or cupola in the upper centre, and operated the vehicle with a steering wheel and system of levers. A mechanic and signalman were also aboard, and soldiers utilised ropes suspended overhead to maintain balance as the tank advanced across rugged terrain.

First World War

MEDIUM MARK A WHIPPET TANK

The Medium Mark A Whippet tank complemented heavier British tanks with battlefield speed and firepower

The Whippet reached the battlefield in early 1918, and its crews first experienced combat during the German Spring Offensive. The Whippets blunted enemy attacks by covering the withdrawal of British troops and enabling them to re-establish defensive lines. At Hébuterne in northern France, a dozen Whippets caught two battalions of German soldiers on the move and forced them to retire.

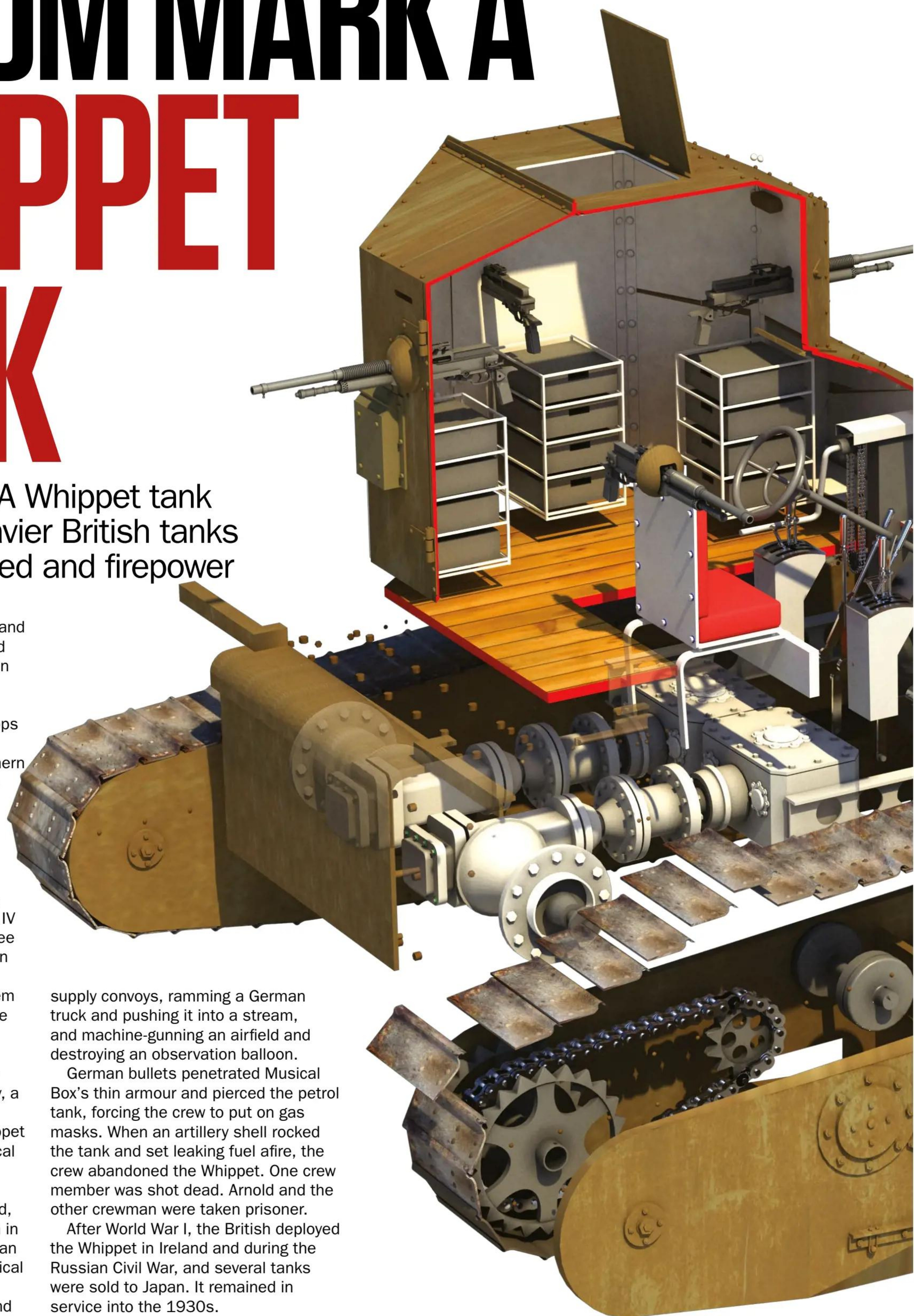
Once the crisis had passed, the Whippets were assigned to tank battalions in company strength. On 24 April 1918, seven Medium Mark A Whippets rushed to the aid of a Mark IV heavy tank just exiting a fight with three German A7V tanks. The Whippets then caught several battalions of German infantry in the open and shredded them with .303-inch machine-gun fire. Some enemy soldiers were crushed under Whippet treads. Approximately 400 Germans were killed. Three Whippets survived the struggle. Later in the day, a Whippet was destroyed by an A7V.

The most memorable wartime Whippet exploit belonged to the crew of 'Musical Box', which terrorised the enemy for nearly 11 hours on 18 August 1918. Commanded by Lieutenant C.B. Arnold, Musical Box dashed through a breach in the enemy line and destroyed a German artillery battery. Unable to retire, Musical Box proceeded to hunt opportunistic targets, attacking infantry columns and

supply convoys, ramming a German truck and pushing it into a stream, and machine-gunning an airfield and destroying an observation balloon.

German bullets penetrated Musical Box's thin armour and pierced the petrol tank, forcing the crew to put on gas masks. When an artillery shell rocked the tank and set leaking fuel afire, the crew abandoned the Whippet. One crew member was shot dead. Arnold and the other crewman were taken prisoner.

After World War I, the British deployed the Whippet in Ireland and during the Russian Civil War, and several tanks were sold to Japan. It remained in service into the 1930s.



CREW COMPARTMENT

Early considerations for the Whippet involved a rotating turret, but that idea gave way to a fixed, polygon-shaped crew compartment, raised to the rear of the chassis and incorporating vision slits. Inside, the compartment was cramped, dark and noisy. Heat from the engine often created extremely high temperatures inside. The compartment was situated behind the engines, and exhaust fumes regularly trailed inside via its ventilation system. Combined with the acrid odour of gunpowder, the noxious fumes were capable of incapacitating crewmen at times. The three-man crew consisted of a commander, gunner and driver, who sat forward and steered by means of a wheel. Although space was limited, sometimes a fourth crewman was added.

DISTINCTIVE TURRET

The distinctive turret of the Whippet made it easily identifiable on the battlefield and gave its crew reasonably good visibility. However, it was also a target for enemy artillery.

ARMAMENT

The light Hotchkiss M1909 machine gun was manufactured in Britain with the label 'Mark I', and 40,000 were completed. The Medium Mark A Whippet was armed with four of the .303-calibre weapons, with a maximum range of 4,160 yards (3,800 metres) and a rate of fire of up to 600 rounds per minute. The Hotchkiss was gas-operated and air-cooled. Fed by a 30-round strip initially and later by belt, it was sometimes prone to jamming, and parts were difficult to replace. The guns were removable from their internal mounts, and occasionally a fourth crewman was aboard the Whippet to operate one or more of the weapons.

TRACKS

The tracks of the Whippet were covered with mud chutes to reduce the possibility of the tank becoming mired in the suck of the Western Front battlefields.

ENGINE

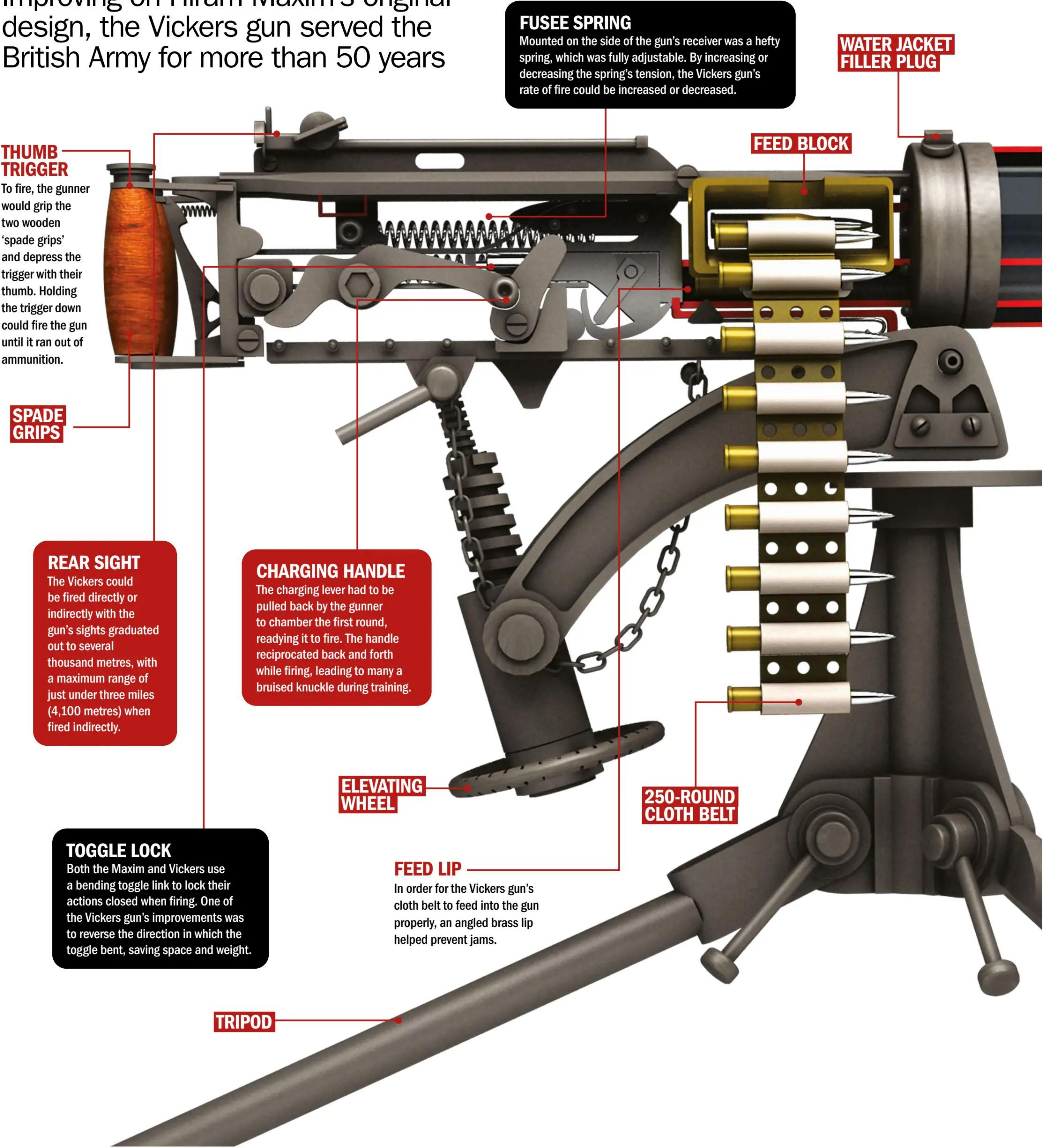
The Tylor Co. traced its origins to the mid 18th century. Its twin four-cylinder, side-valve JB4 petrol engines powered the Medium Mark A Whippet, generating a combined 90 horsepower and a top speed of 8.3 miles per hour (13.4 kilometres per hour). The Whippet's performance was more robust than heavier tanks, particularly considering its comparable weight of 14 tons. The Tylor JB4 engine was similar to those that powered the double-decker buses through the streets of London, and each engine was paired with one of the Whippet's tracks. A complex steering system controlled the throttles of each engine, allowing the driver to execute turns.

SPECIFICATIONS

CREW: 3
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1917
RANGE: 80 MILES (130km)
ARMOUR: 0.5" (14mm)
ENGINE: 2x TYLOR TWIN 4-CYLINDER, SIDE VALVE JB4 PETROL
WEAPONS: 4x .303 MACHINE GUNS

VICKERS-MAXIM GUN

Improving on Hiram Maxim's original design, the Vickers gun served the British Army for more than 50 years





Left: Troops of the Middlesex Regiment carry out maintenance on a Vickers machine gun at Anzio in February 1944

SPECIFICATIONS

COUNTRY OF ORIGIN: UK
IN SERVICE: 1912-68
CALIBRE: 0.303"
LENGTH: 45" (115cm)
WEIGHT: 40lbs (18kg)
MAGAZINE CAPACITY: 250 CANVAS BELT
RATE OF FIRE: 450-500 PER MINUTE

FORESIGHT

BARREL

Without water, the barrel would have overheated within several hundred rounds, eventually ruining its accuracy and causing malfunctions. Even with a full water jacket the barrel would heat up and had to be frequently changed during sustained firing.

DRAIN PLUG

WATER JACKET

With sustained fire, the barrels of machine guns quickly become red hot. To combat this, the Vickers had a water-filled cooling jacket holding around a gallon (4.3 litres). When firing, this evaporated, cooling the barrel. It made the gun heavier and had to be frequently refilled.

MUZZLE CONE

The conical muzzle cone was one of the improvements to the original Maxim. It harnessed gases, leaving the muzzle to help cycle the gun's action. The cone itself was also designed to deflect incoming fire away from the water jacket.

“THE VICKERS GUN ENTERED SERVICE JUST IN TIME TO SEE ACTION DURING WORLD WAR I, WHERE IT PROVED TO BE EXTREMELY RELIABLE EVEN IN THE WORST CONDITIONS”

THE BRITISH VICKERS GUN

The machine gun has dominated the battlefield since its invention in the 1880s, changing the way wars were fought forever. The British Army first used Maxim Guns during the Matabele War in 1893, but by the early 1900s was seeking an improved machine gun. Vickers Ltd developed a lighter, simpler and improved gun that was adopted in 1912. The Vickers gun entered service just in time to see action during World War I, where it proved to be extremely reliable even in the worst conditions. It remained in use throughout World War II and the Korean War before retiring in the late 1960s.

“THE MACHINE GUN HAS DOMINATED THE BATTLEFIELD SINCE ITS INVENTION IN THE 1880s”

British Vickers machine gun crew wearing PH-type anti-gas helmets during the Battle of the Somme in July 1916



FLAMETHROWERS

These weapons of war that hurl fire through the air are now used as tools



Some countries, such as China, maintain the use of flamethrowers in their armies

GREEK FIRE

Flamethrowers aren't a modern invention. In the Byzantine Empire of the late 7th century, a new form of warfare was introduced by an ancient architect named Callinicus of Heliopolis. The incendiary weapon, known as Greek fire, consisted of a liquid fuel that was heated and then pressurised before being ignited and sprayed through a syphon, typically onto the hulls of invading ships. The exact concoction of chemicals used to create the blaze is unknown, but it's been suggested that petroleum and sulphur may have been key ingredients. As a weapon, Greek fire was a formidable foe, as water could not stop the liquid fire from burning. At the time, one of the only known ways to extinguish the fire was by covering it with sand or vinegar.



Left: A illustration of Greek fire from a Byzantine manuscript

Different forms of flamethrowers have existed for thousands of years, but the first handheld flamethrowers emerged during World War I. A creation of the German army, early handheld flamethrowers consisted of backpack-style fuel tanks with gun-like nozzles that, when ignited, released a torrent of flame towards their enemies. Used again in World War II and the Vietnam War as incendiary weapons, it wasn't until 1980 that their use was restricted under Protocol III of the Geneva Convention. Today the main role of flamethrowers lies in land management, such

as eradicating invasive plant species, clearing croplands and burning land to recycle nutrients. For a flamethrower to work, it needs to supply two of the three basic ingredients that cause the reaction that leads to fire: heat and a fuel source. The third ingredient, oxygen, comes straight from the atmosphere. To supply the heat, flamethrowers supply an initial spark when the trigger is pulled and the fuel released. Once the spark ignites the fuel, the heat generated by the fire becomes enough to sustain the reaction. As long as the trigger is held down, gasoline or diesel continues to feed the reaction with atmospheric oxygen.

With all the ingredients needed to create fire, flamethrowers need a way to prevent the flames from travelling back up the device into the tank – with explosive results – when the trigger is pulled. This is achieved by adding a tank of pressurised gas. When the trigger is pulled, the gas forces the fuel through the nozzle, creating a continuous stream of fire in one direction. When the trigger is released, a valve cuts the fuel and oxygen supply off, preventing fire from forming within the flamethrower. This pressurisation also means that flamethrowers can shoot fire over impressive distances. For example, flamethrowers used in World War I could spray fire over 40 metres.

FIGHTING FIRE WITH FIRE

One of the last things you'd expect to see near wildfire is a firefighter holding a flamethrower. Nevertheless, they can be one of the best tools for stopping fire from spreading. Every year, tens of thousands of wildfires sweep through forests and grasslands around the world, destroying habitats and homes. To stop the spread, firefighters use flamethrowers to create what's known as a 'backfire'. This deliberate and controlled fire consumes some of the vegetation in a belt ahead of a spreading wildfire. By the time the wildfire reaches the belt of burnt ground or forest, there is no more fuel to feed the fire, and so the wildlife can't progress any further.

Below: A wildfire raging through a forest in Colorado, destroying wildlife



FUEL TANKS

These two cylinders are filled with flammable oil-based fuel.

COMPRESSED GAS TANK

Compressed flammable gas, such as butane, is fed through a pressure regulator to pressurise the fuel tanks.

TWO TUBES

One tube delivers the fuel directly to the gun and out of the nozzle, while the other supplies pressurised gas to the ignition system.

SPARK PLUG

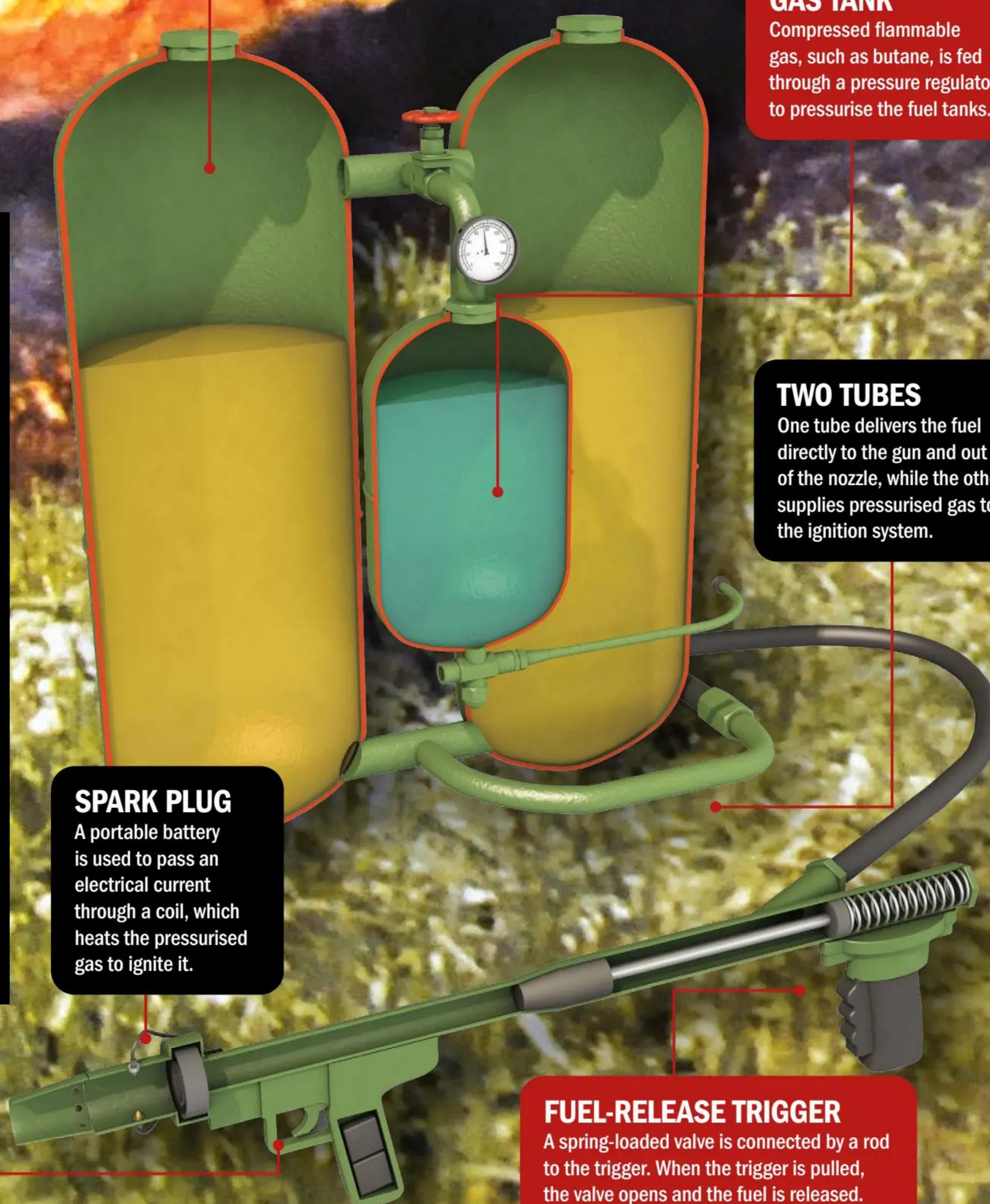
A portable battery is used to pass an electrical current through a coil, which heats the pressurised gas to ignite it.

IGNITION TRIGGER

When the ignition trigger is pulled, a valve holding back the pressurised gas is opened, allowing it to combine with the fuel and pass the spark plug for ignition.

FUEL-RELEASE TRIGGER

A spring-loaded valve is connected by a rod to the trigger. When the trigger is pulled, the valve opens and the fuel is released.



Second World War

PANZER II

This light tank formed the backbone of the Nazi Blitzkrieg

With the end of World War I came the Treaty of Versailles. Among many things limiting Germany were restrictions to its military rights, preventing it from producing armoured vehicles except for a few designated for security. To get around this, the German military ordered the Panzer II be produced under the designation Landwirtschaftlicher Schlepper 100, meaning that it was developed under the guise of being a farm tractor. This was common practice for Germany, and ensured that it wasn't in short supply of armour when war broke out.

THE FRONTAL GLACIS

These only sported the standard amount of armour, which was unusual for a tank, but later received a new single-piece 30mm glacis upon reaching its final Ausf F designation.

7.92MM COAXIAL MASCHINENGEWEHR

Also known by the designation MG 34, the 7.92 machine gun fitted to the Panzer II was an effective anti-infantry weapon and also saw service as a support weapon among Wehrmacht platoons.

20MM MAIN GUN

Produced in Germany in the mid-to-late Thirties, the 2cm KwK 30 L/55 was based on a 20mm flak cannon and was fully automatic, requiring the operator to fire in controlled bursts.

MANUAL TRANSMISSION SYSTEM

The Panzer II sported a six-speed plus reverse manual gearbox made by ZF Friedrichshafen, which was generally considered to be reliable. Reversing was particularly handy for these little tanks.

HAND-CRANKED TURRET

The turret on the Panzer II was actually operated by the tank's commander rather than a specific gunner, as the limited space inside the machine only allowed for three crew members.

VISION PORTS

These were plentiful on the Panzer II, and absolutely essential in both offensive and defensive capacities. A Panzer II commander would operate the turret and so would need a secondary choice of viewport from his turret optics.

HOMOGENOUS STEEL ARMOUR

Early Panzer IIs came with only 0.5 inches (14mm) of armour on the front, sides and back. This was later increased to 1 inch (30mm), and then to 1.4 inches (35mm), but was still largely useless against anti-tank weaponry.

SIX-CYLINDER MAYBACH PETROL ENGINE

The Maybach HL 45 was a six-cylinder petrol engine that saw service in several German vehicles during World War II. It was designed to provide the Panzer II with speed without sacrificing mobility.

TRACK RETURN ROLLERS

The upper part of the continuous track was supported by three return rollers, which were later increased to four on subsequent models of Panzer II for added stability.

RUBBER TYRE ROAD WHEELS

Five of these wheels helped propel the tracks, in turn propelling the vehicle forwards. Later models introduced a torsion bar suspension system for the wheels, whereas early models favoured leaf-type springs.

SPECIFICATIONS

CREW: 3
COUNTRY OF ORIGIN: NAZI GERMANY
COMMISSIONED: 1934
RANGE: 124 MILES (200km)
ARMOUR: UP TO 0.6" (15mm)
ENGINE: MAYBACH HL57TR
WEAPONS: 1x 20mm KWK L/55; 1x 7.92mm MG 34

MATILDA II

Developed in the mid 1930s, this infantry tank was conceived to provide direct fire support for troops on the ground, emphasising armour protection

When the Matilda II Infantry Tank, initially known as the A12 Infantry Tank Mk. II, reached the front lines of the British Army in 1940, its armour protection and two-pounder (40mm, 1.6 inch) main gun made it a formidable weapon, capable of defeating much of the German and Italian armour in the field at the time. Although it shares a common name with its predecessor, the Matilda I, the similarity generally ends there. The Matilda I was intended as an interim design until the Matilda II became available in substantial numbers. The Matilda II was developed with infantry support in mind – speed was a secondary consideration while firepower and armour protection took precedent.

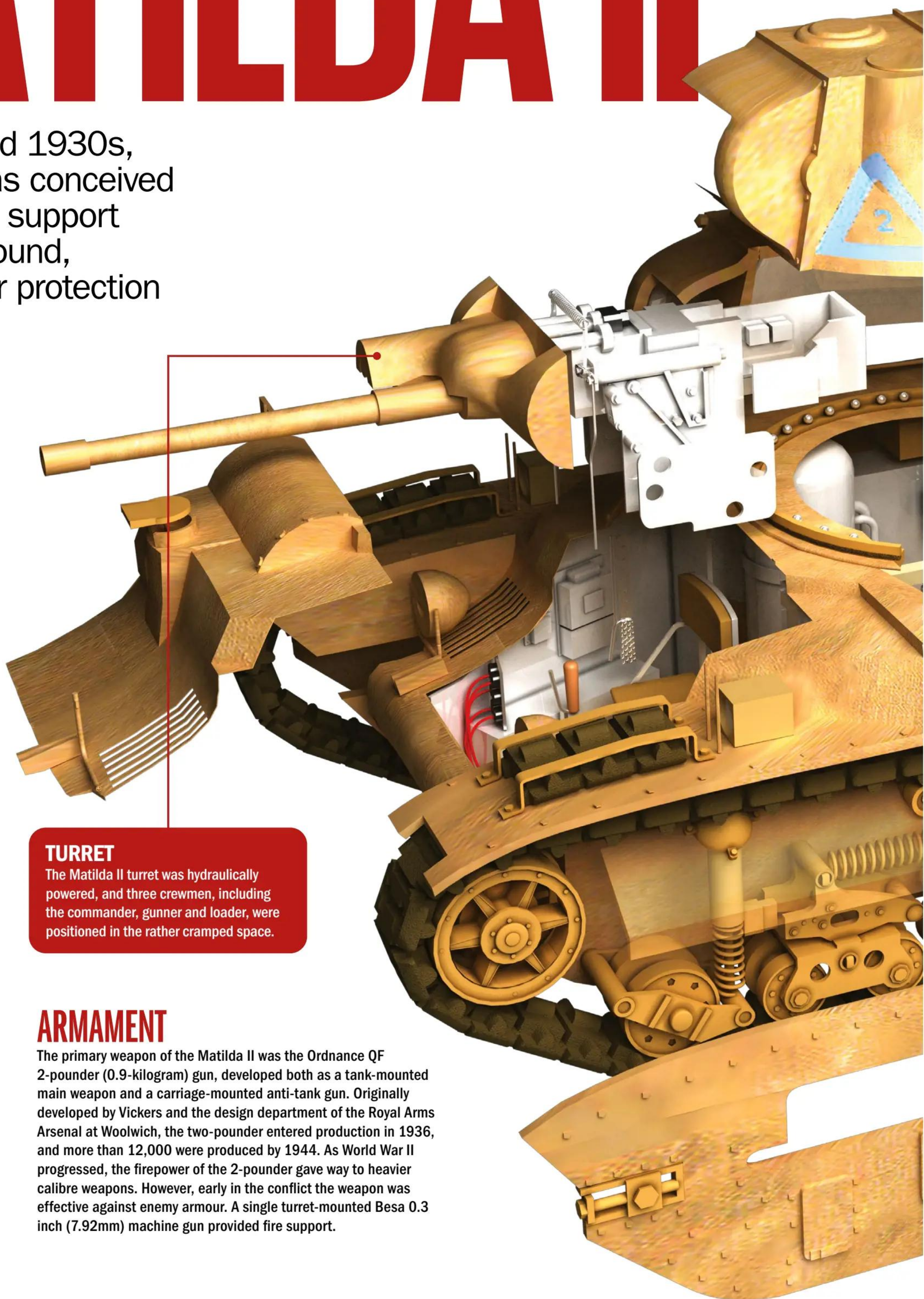
As the Matilda II was deployed to France, it proved impervious to early German anti-tank weapons and vulnerable primarily to heavy-calibre field artillery. Its rugged durability made it a favourite among tank crews, and the Matilda (the designation Matilda II was dropped when the smaller Matilda I was withdrawn from service in 1940) gained fame in the North African theatre during World War II, earning the nickname 'Queen of the desert'. Soon, however, the pre-eminence of the Matilda was eclipsed by heavier German tanks, although it remained in service for the duration of the conflict.

TURRET

The Matilda II turret was hydraulically powered, and three crewmen, including the commander, gunner and loader, were positioned in the rather cramped space.

ARMAMENT

The primary weapon of the Matilda II was the Ordnance QF 2-pounder (0.9-kilogram) gun, developed both as a tank-mounted main weapon and a carriage-mounted anti-tank gun. Originally developed by Vickers and the design department of the Royal Arms Arsenal at Woolwich, the two-pounder entered production in 1936, and more than 12,000 were produced by 1944. As World War II progressed, the firepower of the 2-pounder gave way to heavier calibre weapons. However, early in the conflict the weapon was effective against enemy armour. A single turret-mounted Besa 0.3 inch (7.92mm) machine gun provided fire support.



ENGINE

The Matilda II was powered either by a pair of straight six-cylinder, water-cooled, seven-litre AEC diesel engines – the same that powered London buses – and generating 87 British horsepower, or two Leyland six-cylinder petrol engines generating 95 British horsepower. The tank was slow, capable of a top road speed of only 16 miles per hour (26 kilometres per hour) and a mere nine miles per hour (14 kilometres per hour) cross-country, and its lack of an adequate powerplant limited operations as WWII progressed. A six-speed Wilson epicyclic preselector gearbox

“IT PROVED IMPERVIOUS TO EARLY GERMAN ANTI-TANK WEAPONS AND VULNERABLE PRIMARILY TO HEAVY-CALIBRE FIELD ARTILLERY”

CREW COMPARTMENT

The interior of the Matilda II featured the driver seated forward and centred in the crew compartment. The steering lever was located to the left, and the gear selector to the right. The turret accommodated the commander, gunner and loader, while the engines were positioned to the rear. Crewmen gained entry via the driver's hull hatch or the primary hatch atop the turret. Early in World War II the Matilda's armour protection made the vehicle highly survivable for crews. However, much heavier enemy weapons were later developed, eliminated this appealing feature.

ARMoured SKIRTS

Heavy armour side skirts and mud chutes protected the wheels and tracks of the Matilda II, and improved mobility in difficult terrain and weather conditions.

SPECIFICATIONS

CREW: 4
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1939
RANGE: 160 MILES (257km)
ARMOUR: UP TO 3" (78mm)
ENGINE: 2x LEYLAND 6-CYLINDER
 PETROL; OR 2x 6-CYLINDER AEC DIESEL
WEAPONS: 1x ORDNANCE QUICK FIRING
 2-POUNDER (0.9kg) GUN; 1x 0.3"
 (7.92mm) BESA MACHINE GUN

Second World War

STEN GUN

Developed during Britain’s darkest hour, with Nazi Germany poised to invade, this rough and ready gun was the perfect weapon for the moment

TUBE RECEIVER
The Sten’s design was extremely simple. Its receiver was made from a single piece of tube steel with the barrel, magazine housing and trigger mechanism welded onto it. The Sten’s simplicity allowed millions to be made cheaply.

A SIMPLE REAR PEEP SIGHT

RECOIL SPRING PUSHES THE BOLT FORWARD

COCKING HANDLE

T-SPAR STOCK
During its service life, the British and Commonwealth Sten manufacturers experimented with a variety of stocks. Wooden, folding, collapsible and skeleton stocks were all tried, but the most common was the MkII’s simple T-spar stock.

PISTOL GRIP
The MkII had very basic ergonomics and was uncomfortable to shoot, with just a simple grip welded onto the stock. The MkI had a wooden grip while the MkV introduced a much more ergonomic pistol-style grip.

TRIGGER

FIRE SELECTOR
The Sten could be fired in semi-auto or full-auto. The shooter could select which mode using the weapon’s crossbolt selector button. For full-auto, the crossbolt was pushed through so that it protruded to the left. For semi-auto it protruded to the right.



SAFETY SLOT
The Sten’s design was so simple. It had no safety mechanism other than a slot into which the cocking handle, attached to the bolt, could be placed to prevent it going forward. Troops soon found that if they dropped or jarred the weapon, the bolt could jump out of the safety slot and unintentionally fire the gun.

BREECHBLOCK
The Sten used a simple blowback action. When the trigger was pulled, the breechblock was released forward allowing the firing pin to ignite the cartridge. The gases from the fired cartridge then pushed the breechblock to the rear, starting the cycle over.

The Sten was vital to Britain’s war effort. With the rapid expansion of the country’s small professional army in 1939-40, these forces needed every weapon they could get. The simple, cheap and robust Sten gun offered a weapon that could be rapidly manufactured for as little as 15 shillings. The most basic version of the Sten had fewer than 50 parts and could be made in small factories and workshops with basic tools. While the Sten wasn’t the most reliable or the best submachine gun of the war, more than 4 million were made, equipping British and Commonwealth troops and resistance fighters all over Europe. The Sten played a small, important role in winning WWII.

SPECIFICATIONS

COUNTRY OF ORIGIN: UK
SERVICE DATES: 1941-1956
CALIBRE: 9x19mm
LENGTH: 30" (76.2cm)
WEIGHT: 6.5lbs (3kg)
MAGAZINE CAPACITY: 32 ROUNDS
RATE OF FIRE: 550 ROUNDS PER MINUTE

FRONT SIGHT

The MkII's sights were extremely rudimentary. The rear sight was a simple peep while the front sight was a piece of folded and welded triangular metal. These were later improved with proper sights added to the more refined MkV.

PUSH BUTTON MAGAZINE RELEASE

SPENT CASES EXIT FROM THE EJECTION PORT

MAGAZINE HOUSING

Unlike the German MP40 or American Thompson, the Sten's magazine was loaded into the weapon from the side. This had the benefit of enabling soldiers to get low, close to the ground and still be able to use their weapon.

BARREL

The MkI Sten initially had six rifling grooves inside its barrel, but with the simplification of the MkII, this was reduced to two. The Sten's barrel was 19.6 centimetres long, much shorter than the PPSH-41, Thompson and MP40.

BARREL SHROUD

The Sten has few creature comforts but the barrel shroud was needed to give troops somewhere to hold the weapon. Holding it too tightly by its magazine could prevent the gun from feeding reliably.

A British paratrooper poses with a new MkII Sten Gun in October 1942

"OVER FOUR MILLION WERE MADE, EQUIPPING BRITISH AND COMMONWEALTH TROOPS AND RESISTANCE FIGHTERS ALL OVER EUROPE"

PANZERKAMPFWAGEN V

PANTHER

The finest all-around tank of WWII, the Panther was built in response to the Soviet T-34

About 250 Ausf. D Panthers entered service in January 1943 and took part in the epic Battle of Kursk that summer. Many of these were lost to mechanical breakdown. Larger engines, redesigned armour skirts and a re-engineered turret were added in a production run that ended in September 1943. A total of approximately 850 Ausf. D Panthers were manufactured before giving way to the improved Ausf. A, and about 2,200 of these were built with maximum armour protection upgraded to 4.72-inch (120mm) thickness. The most numerous Panther variant, the Ausf. G, entered production in the spring of 1944, and nearly 3,000 were completed by 1945, incorporating an upgraded exhaust system, a rotating periscope to improve the driver's field of vision, and tapered armour on the upper hull.

Once its mechanical difficulties were sorted out, the Panther became a fearsome battlefield presence on both the Eastern and Western fronts, as evidenced at the French village of Le Lorey in late July 1944, when Oberscharführer (technical sergeant) Ernst Barkmann, the most prolific Panther

ace of World War II, waited in ambush as an American armoured column slowly approached.

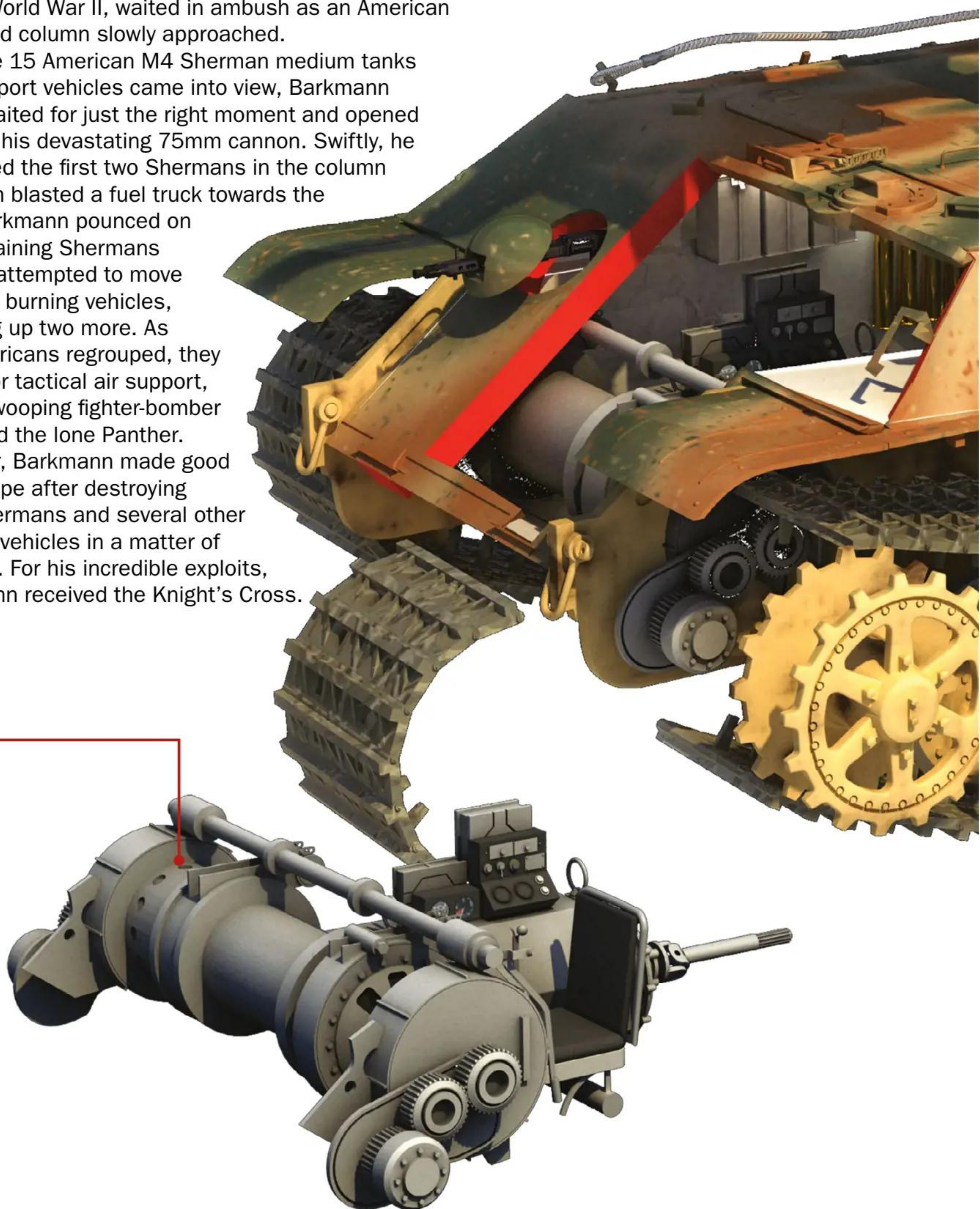
As the 15 American M4 Sherman medium tanks and support vehicles came into view, Barkmann coolly waited for just the right moment and opened fire with his devastating 75mm cannon. Swiftly, he destroyed the first two Shermans in the column and then blasted a fuel truck towards the rear. Barkmann pounced on the remaining Shermans as they attempted to move past the burning vehicles, shooting up two more. As the Americans regrouped, they called for tactical air support, and a swooping fighter-bomber damaged the lone Panther. However, Barkmann made good his escape after destroying nine Shermans and several other support vehicles in a matter of minutes. For his incredible exploits, Barkmann received the Knight's Cross.

CONTROL

The Panther tank's MAN single radius steering system was operated by levers from the driver position located forward in the hull. The driver was required to judge the distance to a turn and use a combination of appropriate gear and brake to accomplish it. The gearbox was a seven-speed AK 7-200 designed by Zahnradfabrik Friedrichshafen.

ENGINE

The primary engine of the production Panther, the V-12 Maybach HL 230 P30 gasoline engine, generated 690 horsepower, or 514.5 kilowatts of power, with a top speed of 29 miles (46 kilometres) per hour. The HL 230 also powered the Panther tank destroyer variants and the heavy Tiger tank models. The HL 230 was an upgraded version of the smaller original HL 210 gasoline powerplant, yielding enhanced performance and generally eliminating problems with overheating, bearing burnout, and connecting rods that had plagued the early-production Panthers. The HL 230 remained in high demand throughout World War II, and approximately 9,000 were manufactured in total.



TURRET

The Panther turret had already been developed when the tank itself was in the design phase, and numerous alterations were introduced. Its sloped armour offered increased protection against incoming projectiles.

ARMAMENT

The main weapon of the PzKpfw. V Panther was the 75mm high-velocity KwK 42 L/70 cannon made by Rheinmetall-Borsig. Capable of penetrating up to 5.9 inches (150mm) of armour at a range of 1,094 yards (1,000 metres), the KwK 42 L/70 was superior to the main weapons of most Allied tanks. Up to 48 rounds of ammunition were stored in sponsons on either side of the turret; no live ammunition was stored in the turret itself. The breech operated semi-automatically, ejecting spent shell casings. The L/70 was fired with electrical current rather than a firing pin. A pair of 7.92mm MG-34 machine guns protected against infantry.

ARMOUR

The armour protection on the top of the Panther tank's three-man turret was 0.59 inches (15mm) thick, the thinnest in its design. Like other armoured vehicles of its era, the Panther was vulnerable to attack from Allied fighter-bombers.

WHEELS

A double torsion bar suspension supported the Panther's system of eight steel interleaved road wheels that were rimmed with rubber. The configuration made changing interior road wheels a time-consuming operation, particularly under battlefield conditions.

SPECIFICATIONS

CREW: 5
COUNTRY OF ORIGIN: NAZI GERMANY
COMMISSIONED: 1942
RANGE: 124 MILES (200km)
ARMOUR: 0.59" (15mm)
ENGINE: V-12 MAYBACH HL 230 P30
WEAPONS: 75mm KWK 42 L/70 LONG-BARRELED CANNON; 2x 7.92mm MG-34

"THE PANTHER WENT ON TO WIN PRAISE FROM ITS CREWS AND EARN A FEARSOME REPUTATION AMONG ITS ADVERSARIES"

KING TIGER

The Tiger II was the largest tank used by Nazi Germany in WWII, but the behemoth was problem-prone and never had the impact on the battlefield its creators had sought

The first 50 Tiger IIs were fitted with the Krupp-designed early production rounded front turrets



The Tiger II was the largest and heaviest operational tank used by Nazi Germany during the Second World War. It was designed to break through enemy lines, smash their defences and knock out their armour with its powerful gun. By 1942, the Soviet Union was proving to be a far harder nut to crack than expected. Something had to be done to turn the tide on the battlefield. The decision? A tougher, larger and more powerful tank. German High Command wanted a deadlier Tiger, armed with a higher-velocity gun capable of penetrating new, thicker Soviet armour at longer distances. Two firms, Porsche and Henschel, were given the task of designing the new hull, while Krupp had the responsibility of creating the turrets for each design.

When the Tiger II engaged in battle with enemy armoured formations it proved to be a formidable opponent, but these occasions were few and far between. In fact, more Tiger II tanks were destroyed by their crews than enemy action. Being extremely heavy, the German Army did not have enough suitable resources to recover them if they broke down because of a mechanical fault, enemy action or they just got stuck in the mud. To prevent their machines from falling into enemy hands and being turned on their former masters, tank crews would often destroy their crippled vehicle before abandoning it.



A Tiger II fitted with the Krupp production turret painted in 'ambush' camouflage belonging to the Heavy SS-Panzer Battalion 501 (s.SS Pz.Abt. 501)

“WHEN IT ENGAGED IN BATTLE WITH ENEMY ARMoured FORMATIONS IT PROVED TO BE A FORMIDABLE OPPONENT”



Each Heavy Panzer Battalion was issued with 45 Tiger II tanks



Tiger II tank 113 of s. SS Pz.-Abt. 101, driving through Beauvais, France, 30 August 1944

KRUPP'S FIGHTING VEHICLE CANNON
The 88mm KwK 43 L/71 high velocity gun was the most powerful weapon of its kind mounted in a tank during World War II. The L/71 entered production in 1943, and was introduced with the Tiger II, or King Tiger. Its barrel length of 21 feet (6.43m) was over three feet longer than the L/56 mounted on the Tiger I, and its muzzle velocity reached an astonishing 3,280 feet (1,000 metres) per second.



Above: Tiger II tank 113 ran out of fuel near Mons, Belgium, in 1944. The gun is pointing to the rear in anticipation of being towed but US Forces liberated the city before that could happen

Vast resources were required to build just a single Tiger II, and by this stage in the war they were being produced at a time of shortages and heavy Allied bombing of German factories and infrastructure. It has often been said that the Germans should have abandoned these heavy tank projects and concentrated on building greater numbers of Panzer IV tanks, which required far fewer resources to build.

The Tiger II was known by many names both during and after its development. The final official German designation was Panzerkampfwagen Tiger Ausf. B, which was sometimes shortened to Tiger B. The Tiger II's German Sonderkraftfahrzeug ('special purpose vehicle', abbreviated to Sd.Kfz.) ordnance inventory designation was Sd.Kfz.182. It was also informally called the Königstiger (German for Bengal tiger, not King Tiger). Allied documentation referred to it as the Tiger II, King Tiger or Royal Tiger.

ARMOUR PLATING
The front hull glacis plate armour was 5.9 inches (150mm) thick and the lower front was 3.9in (100mm). Both were set at an angle of 50 degrees, increasing the effective thickness of the armour to any horizontal incoming fire.

TORSION BAR SUSPENSION
The Tiger II's traverse torsion bar suspension helped minimise cross-country instability. However, the nine overlapping road wheels on either side of the hull continually required maintenance due to trapped debris. In winter conditions, the wheels would sometimes freeze together, requiring the crew to remove ice before the tank could operate.

TURRET

Production-line King Tigers dispensed with the rounded front of the turret and bulge in the commander's cupola. The cupola could be mounted with an extra machinegun for anti-aircraft fire.



Above: The Tiger II's front hull and turret armour could not be penetrated by most Allied anti-tank guns. The more vulnerable side and rear armour were not as thick

ENGINE

The Maybach HL 230 P30 V-12 water-cooled 23-litre 750hp petrol engine gave the tank a maximum road speed of 23.6mph (38km/h) and an average road speed of 21.74mph (35km/h).

AMMUNITION CAPACITY

The Tiger II carried a mixture of up to 80 rounds of armour-piercing and high-explosive ammunition for its 88mm gun. The rounds were stored at the rear of the turret, and along the right side of the hull, offering the easiest access for the loader during operations.

SPECIFICATIONS

CREW: 5
COUNTRY OF ORIGIN: NAZI GERMANY
COMMISSIONED: 1944
RANGE: 6.2 MILES (10km)
ARMOUR: UP TO 5.9" (150mm)
ENGINE: MAYBACH HL 230 P30 V-12 PETROL
WEAPONS: 88mm KW.K.43 L/71 GUN;
COAXIAL AND BALL-MOUNTED MACHINE GUNS;
CUPOLA-MOUNTED AA GUN

CENTURION

MAIN BATTLE TANK

The British Centurion main battle tank is remembered as one of the best all-round designs of the Cold War era

The Centurion developed a reputation as perhaps the foremost tank of the Cold War. While its weight limited the tank's deployment during the Korean War, its performance was exceptional. Many observers considered the Centurion the 'universal tank'. In the Korean War, the tank earned high praise while in use with the 8th King's Royal Irish Hussars, covering the retreat of the 29th Infantry Brigade at the Battle of the Imjin River.

During the Vietnam War, 58 Centurions were deployed with the Royal Australian Armoured Corps, and Centurions of the Indian army fought US-made Pakistani army tanks during conflicts in 1965 and 1971. Israeli Defense Force Centurions performed admirably against Soviet

and US-made tanks of opposing Arab forces during the Six-Day War in 1967 and the Yom Kippur War of 1973. Into the 1980s, the Israelis deployed the Centurion in Lebanon.

The service life of the Centurion spans well over half a century, and some remain in service today with armed forces around the world.

DRIVER

The Centurion's driver was positioned in the tank's bow and steered the vehicle with levers. He operated the hull-mounted machine gun in some variants.

SPARE TRACK LINKS

IDLER WHEEL

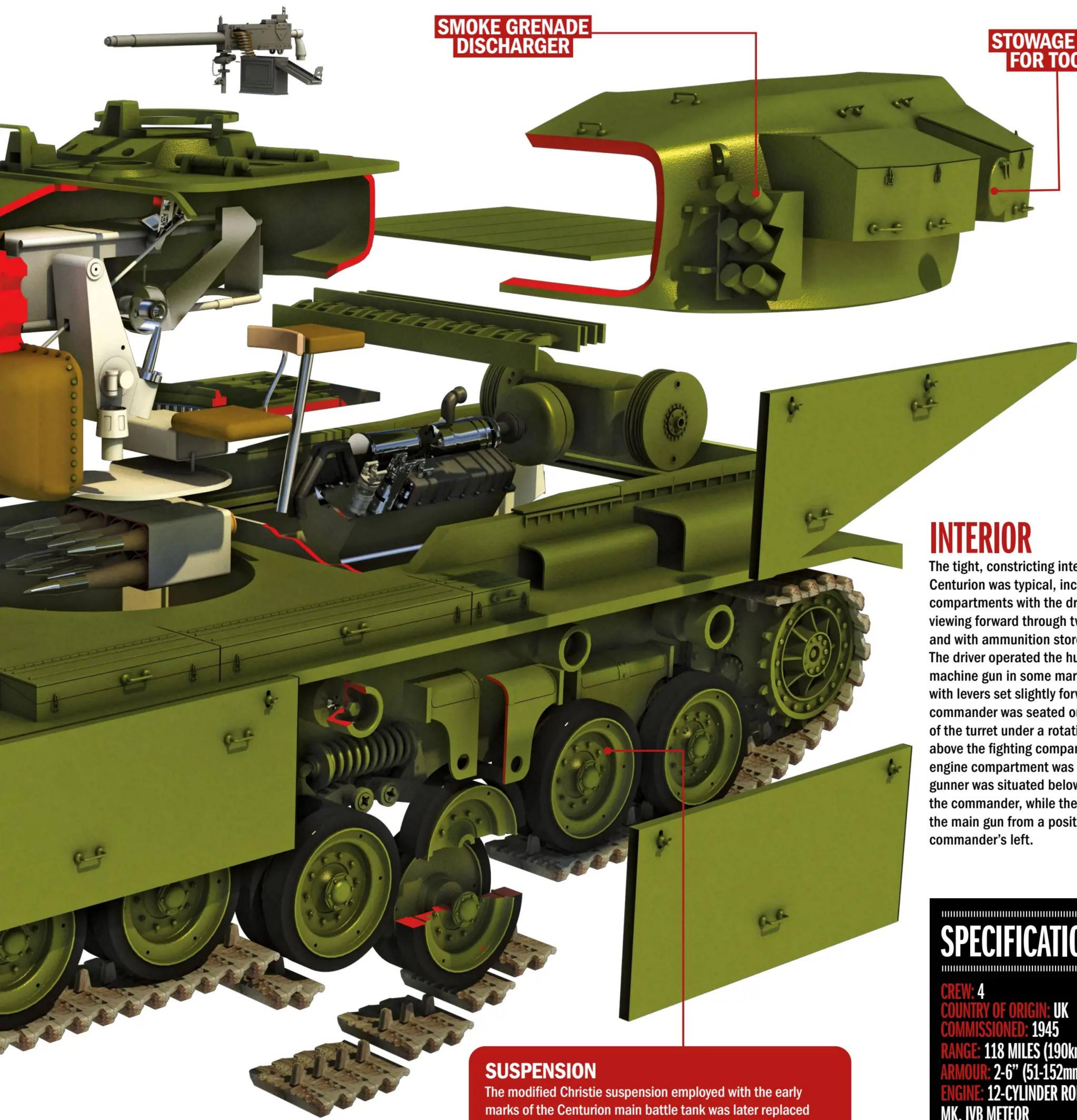


ENGINE

The Rolls-Royce Meteor engine was a development of the company's famous Merlin aircraft engine and was adapted for use in tanks by a team headed by engineer W.A. Robotham with the Chassis Design and Development Group at Clan Foundry, Belper. The engine entered production in 1941, and thousands were completed before the run ended in 1964. Powering the Centurion, the 12-cylinder petrol engine produced 650 horsepower and a top speed of 22 miles (35 kilometres) per hour. The Israeli Defense Force upgraded its Centurions with the 900-horsepower Teledyne Continental AVDS-1790-2R diesel engine.

ARMAMENT

The earliest operational Centurions were armed with the QF 17-pounder (76.2mm/three-inch) antitank gun modified to fit inside its turret, and later the 20-pounder (84mm/3.3 inch). However, beginning with the Mk. 5, the primary weapon became the famed 4.1-inch (105mm) L7 rifled gun. Developed and built by the Royal Ordnance Factory, the L7 is considered the finest tank gun ever produced in the UK. Developed in the 1950s, its was first installed on the Centurion at the end of the decade. Its rate of fire is up to ten rounds per minute.



INTERIOR

The tight, constricting interior of the Centurion was typical, including three compartments with the driver in the bow, viewing forward through two periscopes and with ammunition stored to his left. The driver operated the hull-mounted machine gun in some marks and steered with levers set slightly forward. The commander was seated on the right side of the turret under a rotating cupola above the fighting compartment. The engine compartment was to the rear. The gunner was situated below and in front of the commander, while the loader serviced the main gun from a position to the commander's left.

SPECIFICATIONS

CREW: 4
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1945
RANGE: 118 MILES (190km)
ARMOUR: 2-6" (51-152mm)
ENGINE: 12-CYLINDER ROLLS-ROYCE
MK. IVB METEOR
WEAPONS: 105mm (4.1") L7A2 RIFLED
GUN; COAXIAL BROWNING .30-CALIBRE
MACHINE GUN

SUSPENSION
The modified Christie suspension employed with the early marks of the Centurion main battle tank was later replaced with a Horstmann suspension, with external horizontal springs.

M1 ABRAMS MAIN BATTLE TANK

Since its debut in the 1980s, the M1 Abrams tank has maintained a combat edge on the modern battlefield

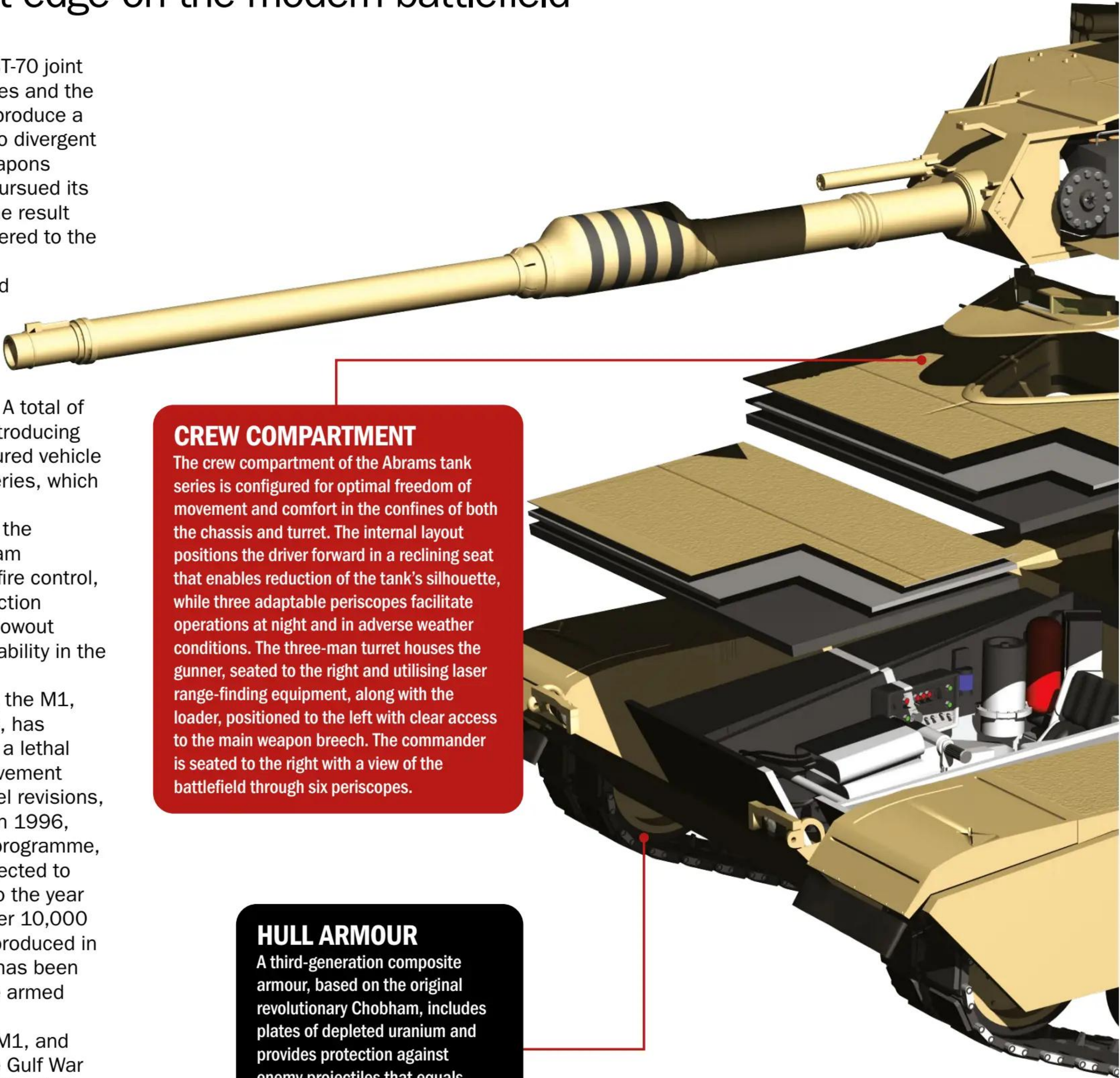
In the mid-1970s, the lengthy MBT-70 joint venture between the United States and the Federal Republic of Germany to produce a main battle tank collapsed due to divergent priorities with the developing weapons system. As a result, each country then pursued its own programme. In the United States, the result was the prototype XM-1, which was delivered to the US Army for field evaluation in 1976.

By 1978, Chrysler Corporation initiated production, and two years later the first operational M1 Abrams third-generation main battle tank entered service, a contemporary of the German Leopard 2 main battle tank. A total of 3,273 M1 tanks were built for the US, introducing to the American arsenal a modern armoured vehicle replacing the latest in the Patton tank series, which had served since the 1950s.

The M1 had modern features such as the multi-fuel gas turbine engine and Chobham composite armour, along with computer fire control, NBC (nuclear, biological, chemical) protection and separate ammunition storage in a blowout compartment that enhanced crew survivability in the event of a catastrophic explosion.

During more than 40 years of service, the M1, named for US General Creighton Abrams, has proven itself, with major upgrades, to be a lethal presence on the battlefield. Major improvement programmes have led to significant model revisions, including the M1A1 in 1985, the M1A2 in 1996, the current M1A2 SEPV3 enhancement programme, as well as the M1E3 upgrade that is expected to extend the service life of the Abrams into the year 2040 and perhaps even beyond. Well over 10,000 Abrams tanks of all variants have been produced in the last half-century, and the M1 series has been purchased by or entered service with the armed forces of at least ten countries.

The impressive combat record of the M1, and successor Abrams variants, includes the Gulf War of 1991, the 'Global War on Terror' (specifically in Iraq and Afghanistan), the Iraq War, the Ukraine War and other international deployments. It has demonstrated significant prowess against tanks constructed during the Soviet era.



CREW COMPARTMENT

The crew compartment of the Abrams tank series is configured for optimal freedom of movement and comfort in the confines of both the chassis and turret. The internal layout positions the driver forward in a reclining seat that enables reduction of the tank's silhouette, while three adaptable periscopes facilitate operations at night and in adverse weather conditions. The three-man turret houses the gunner, seated to the right and utilising laser range-finding equipment, along with the loader, positioned to the left with clear access to the main weapon breech. The commander is seated to the right with a view of the battlefield through six periscopes.

HULL ARMOUR

A third-generation composite armour, based on the original revolutionary Chobham, includes plates of depleted uranium and provides protection against enemy projectiles that equals roughly 38-inch (965mm) of rolled homogeneous steel. The improved armour provides greater protection and survivability for the crew.

SECONDARY ARMAMENT

The 0.5-inch (12.7mm) M2HB heavy machine gun is turret-mounted aboard the M1 Abrams tank series and represents a modernisation of the famed M2 .50-calibre machine gun developed by John Browning. A pair of .30-calibre machine guns provides close support against infantry attack or allows the tank to add small-arms fire in an assault.



M1 Abrams main battle tanks manoeuvre during exercises in Operation Reforger, 1985

TURRET

The characteristic low-profile turret of the M1 Abrams tank series contributes to an overall minimal silhouette for the vehicle and houses three of the tank's four crewmen: gunner, loader and commander. The turret is further configured to accommodate the breech of the main 4.7-inch (120mm) weapon and technology for target acquisition, navigation and sophisticated armour protection.

POWERPLANT

The Honeywell AGT1500 gas turbine engine installed with the M1 Abrams tank series was a great leap forward in armoured vehicle propulsion. The multi-fuel engine generates 1,500hp, a top speed of 42mph (68kp/h) and tremendous acceleration. Nicknamed 'Whispering Death,' the engine is noted for quiet running.

SPECIFICATIONS

- CREW: 4
- COUNTRY OF ORIGIN: USA
- COMMISSIONED: 1980
- RANGE: 265 miles (426km)
- ARMOUR: UP TO 37.7" (960mm)
- ENGINE: HONEYWELL AGT 1500
- WEAPONS: 4.7" (120mm) M256 SMOOTHBORE GUN; .50-CALIBRE M2HB MACHINE GUN TURRET MOUNTED; 2x .30-CALIBRE MACHINE GUNS

ARMAMENT

Early Abrams tanks mounted a main armament of the 4.1in (105mm) M68 A1 rifled gun, constructed on a British Royal Ordnance design. With the M1A1, the primary weapon was replaced by the 4.7in (120mm) M256 smoothbore gun adapted from the German Rheinmetall L44 weapon and built under licence. The M256 is capable of firing an array of ordnance, including the M829A4 advanced multi-purpose (AMP) round. Experiments with the longer 4.7in (120mm) L55 have likely resulted in maintaining the L44 as the M1 series primary weapon. Secondary .30-calibre and .50 calibre machine guns provide defence against infantry and lower level air attack.

Right: The 4.7in (120mm) smoothbore M256 main weapon mounted by the M1A1 Abrams is prominent in this photo of a Marine tank off-loading



“THE M256 IS CAPABLE OF FIRING AN ARRAY OF ORDNANCE, INCLUDING THE M829A4 ADVANCED MULTI-PURPOSE (AMP) ROUND”

US Army M1 Abrams manoeuvre into firing positions during Operation Reforger, 1985



An Australian soldier mans the turret-mounted .50-calibre M2HB machine gun aboard an Abrams tank, 2021



An M1A1 Abrams tank fires its M256 main weapon, a licence-built version of the German Rheinmetall L44



SERVICE HISTORY

The US government approved the enhancement of 1,000 tanks to the M1A2 standard in 1996. The upgrade, performed at Lima Army Tank Plant in Ohio, validated the long-term investment in the Abrams. That investment had been justified to a great extent by the combat performance of the M1 series during the Gulf War of 1991. Although 14 Abrams tanks were damaged and nine destroyed during the Gulf War, none were lost to enemy tank fire. Seven were destroyed in incidents of friendly fire, and two intentionally to prevent capture by hostile forces.

In tank versus tank combat, the Abrams was clearly superior to the Soviet-made T-72, T-62 and T-54/55 tanks deployed by Iraqi forces. A total of 1,848 M1A1 tanks were deployed to Saudi Arabia during Operation Desert Storm.

The most famous Abrams performance during the Gulf War on occurred at the Battle of 73 Easting and a follow-up action at Objective Norfolk, 26-27 February 1991. At 73 Easting, four troops of the US 2nd Armored Cavalry Regiment destroyed two brigades of the Iraqi Tawakalna Division. Nine M1A1 Abrams tanks, accompanied by a dozen Bradley fighting vehicles, blasted dozens of enemy tanks and armoured vehicles. Only one Bradley was lost to hostile fire. After two days of fierce combat, over 200 Iraqi armoured vehicles had been destroyed.

Later, performance in the Iraq War further burnished the Abrams's reputation. In the autumn of 2023, the US Army announced the M1E3 modernisation programme, which is expected to further increase the system's longevity.



This M1A1 Abrams photographed in the field in 2007 exhibits the characteristic low profile and features of the TUSK urban enhancement package

DESIGN

The Abrams main battle tank series was designed to provide the most capable and robust armoured vehicle platform in the world in both offensive and defensive roles, particularly in the event of war in Europe with the Soviet Union and Warsaw Pact countries. Enhanced crew survivability was complemented in the original design with modern features. The design itself was intended to present a low profile, maximise the enhanced armour protection incorporated, and allow newly introduced target acquisition systems to operate with efficiency. More than a dozen upgrades were applied to the M1A1 alone, including the Tank Urban Survival Kit series (TUSK) that allowed greater security and proficiency in close-quarter urban environments.



M1A1 Abrams main battle tanks of the 3rd Armored Division move out on a mission during Operation Desert Storm



A Honeywell AGT 1500 gas turbine engine is eased into the engine compartment of an Abrams tank in Kuwait

ENGINES

With the introduction of the M1 Abrams, the US military broke the tradition of the diesel engines that had powered its armoured forces for decades. The Honeywell AGT 1,500-horsepower gas turbine engine, designed and built by Lycoming Textron, has earned a reputation for reliability in varied environmental conditions such as the temperature extremes of desert warfare, and its multi-fuel powerplant makes considerably less noise than its diesel predecessors. Providing an exceptional surge of power as needed, the gas turbine enables the Abrams to reach optimal cruising speed in a matter of seconds and rapidly hit a top speed of 42mph (68kp/h).

THE HUMVEE

The high-mobility multipurpose wheeled vehicle (HMMWV) roars off the production line ready for action

Designed to replace several outdated American military vehicles, the high-mobility multipurpose wheeled vehicle, or Humvee, has been in production since 1985. Originally intended as a light utility vehicle, there have been more than 20 variants of this highly customisable, modular platform. Serving over 40 nations, around 200,000 Humvees have been built to date. Able to carry and deploy almost anything, from fully armed troops to anti-aircraft missiles, the Humvee is an open-topped scout vehicle, an armoured personnel carrier, ambulance, a TOW missile launcher, a communication centre, a heavy machine gun platform and whatever else the situation requires. The latest models are unrivalled in their off-road capability, and are based around a 1.7-gallon (6.5-litre) V8 Turbo diesel engine which produces 190 brake horsepower (142 kilowatts) and 380 pounds force per foot (515 Newtons per metre) of torque. This power is sent to all four wheels through an electronically

controlled four-speed automatic gearbox, using a series of differentials. The drivetrain is rather unconventional as the wheels themselves contain portal-gearred hubs, which not only double the torque generated, but due to the offset driveshaft inputs, enable the vehicle's ground clearance to be significantly higher than a regular centre axle would allow. This innovative drivetrain, coupled with independent suspension and 37-inch (94-centimetre) tyres, enable the Humvee to travel at 70 miles (113 kilometres) per hour or to climb slopes of 60 per cent – though some Humvees have been seen to climb near-vertical walls! The internal environment is fully air conditioned, while a deep-water fording kit allows the vehicle to cross rivers almost completely submerged. These capabilities, combined with design features such as the sturdy chassis, corrosion resistance plus high commonality and interchangeable parts, enable the Humvee to be flexible, dependable and rugged even in the harshest of environments.

ARMOUR

Since the Humvee was introduced, soldiers have demanded increasingly more protection from it. Early versions had fabric doors and no roof, but the demands of Somalia, Iraq and Afghanistan demonstrated the need for improved armour. Many improvised solutions have been tried in the field in recent years, including sandbags and welding scrap metal to the chassis. However, heavily armoured versions are now available from the factory, as are retrofit kits, which include under-body plates, heavy doors, armoured seats, weapon shields and many other additions. The latest iterations offer the crew protection from assault rifle bullets, some air-burst artillery, and up to 12 pounds (5.4 kilograms) of explosives, thanks to thick steel armour, energy-absorbing coatings and mounting, and reinforced glass. All of this comes at a price, though, with many Humvees carrying 2,000-4,000 pounds (907-1,814 kilograms) of armour, which can only be taken in place of cargo and equipment. Work is underway to make the Humvee more resistant to buried explosives, as the large flat floor is not effective against these.



HARD TARGET
Armour configurations vary from having doors that weigh more than a heavyweight boxer to having no doors at all.

TURRET

A huge selection of weapons can be fired from the turret position.

SNORKLE

The snorkel here (and raised exhaust, see far right) allow the vehicle to submerge in water up to 4.9ft (1.5m).

CLIMATE CONTROL

Air conditioning is a welcome feature when operating in hot countries.

LIGHTWEIGHT

Riveted and bonded aluminium body panels give good strength, low weight and flexibility to help off-road performance.

RUGGED CHASSIS

All Humvees share common components to help serviceability, including the chassis frame.

PROTECTION

The important mechanical parts are protected high up within the vehicle, including the drivetrain and disc brakes.

DIESEL POWER

The massive V8 diesel engine produces lots of torque to give excellent rough terrain capability.

4X4

Three differentials ensure power goes to the wheels at all times, giving high traction.

SPECIFICATIONS

COUNTRY OF ORIGIN: USA
COMMISSIONED: 1985
CREW: 2 PLUS UP TO 8 PASSENGERS
RANGE: 250-350 MILES (400-560km)
TOP SPEED: OVER 70mph (113km/h)
ENGINE: 6.5L DETROIT DIESEL V8
PRIMARY WEAPON: M2 BROWNING .50 CALIBRE MACHINE GUN

PORTAL HUBS

The large wheels contain the portal gearing, and the tyre pressures can be altered remotely from the driver's seat.

WEAPONS

There was always a requirement to arm the Humvee to provide fire support and self-defence, but the variety of weapons it can carry is astonishing. Starting with a choice of general-purpose machine guns, most weapons can be fired manually or fitted to the remotely operated CROWS turret system. The most common weapon choice is the legendary M2 Browning .50 Calibre. However, should there be a need to raze everything in sight to the ground, the gunner can unleash 100 shots per second using the awesome M134 minigun. For even bigger bangs, the 1.6-inch (40-millimetre) grenade machine gun can launch 60 high-explosive grenades per minute. Should an enemy bring a tank to the fight, the Humvee can launch the TOW anti-armour missile from 2.3 miles (3.8 kilometres) away, or in situations requiring a little bit of overkill, the Humvee is designed to tow a Howitzer cannon. The ultimate version, however, has to be the Boeing-developed Avenger, which carries up to eight stinger anti-aircraft missiles, with proposals for additional weapons including a one-kilowatt laser.

CHALLENGER 2

The British Army's Main Battle Tank is one of the most sophisticated weapons of its kind

ARMOUR PROTECTION
State-of-the-art Chobham composite armour protects the Challenger 2 main battle tank, and is reportedly stronger than multiple layers of steel. The precise composition of the armour remains classified.

CREW COMPARTMENT
The four-man crew of the Challenger 2 is seated inside the turret and chassis. The commander occupies a position in the turret to the right with the loader to his left. The driver and gunner are seated below in the hull.

L30A1 120MM MAIN WEAPON
Manufactured by BAE Land Systems from electro-slag refined (h) steel, the L30A1 120mm (4.7-inch) rifled gun is equipped with a thermal sleeve, fume extractor and muzzle reference system. Sometimes referred to as the CHARM (Challenger Main Armament) Gun, it is 55 calibres long.

FUME EXTRACTOR

GRENADE LAUNCHERS

THERMAL IMAGING SENSORS

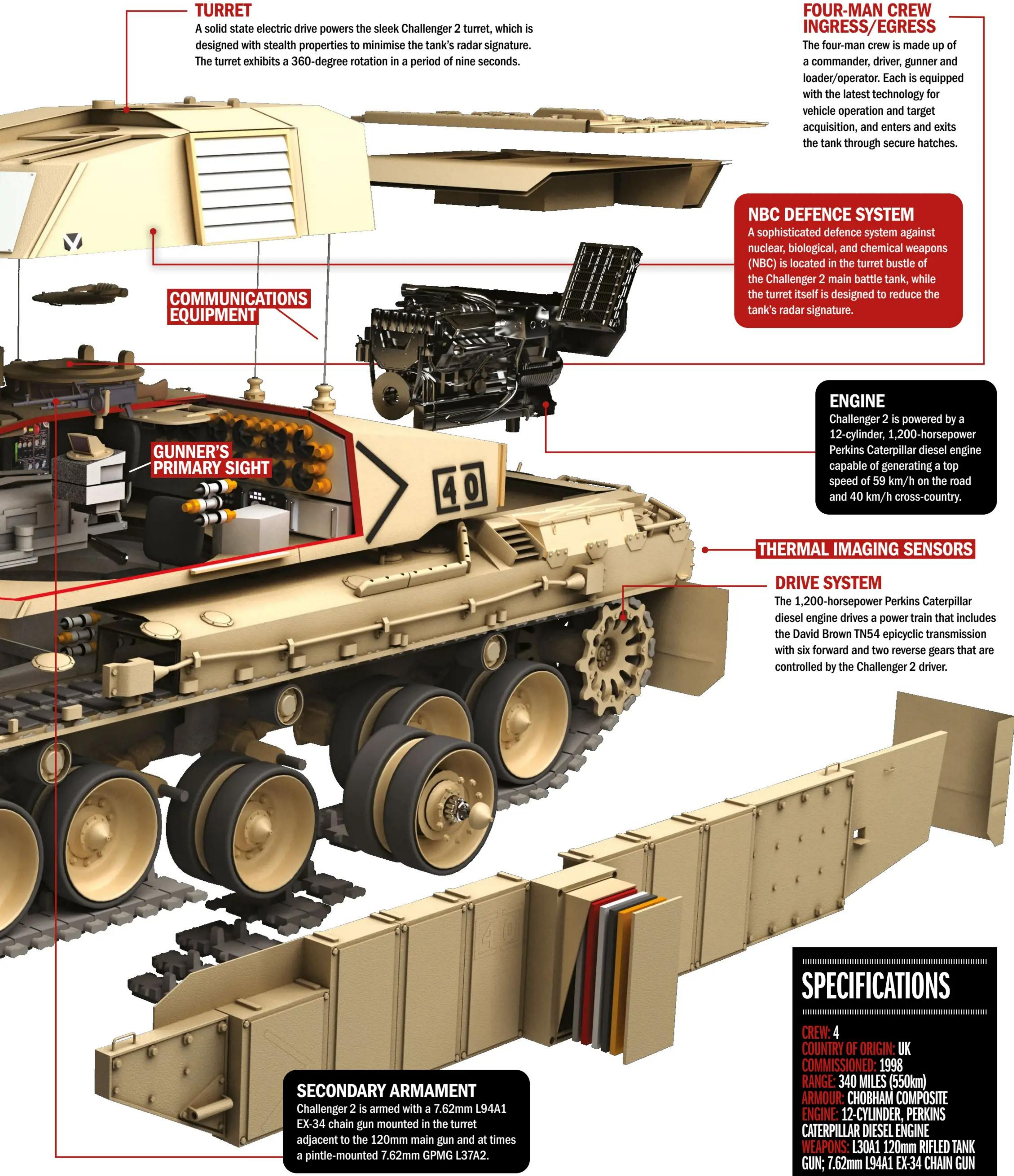
This main battle tank entered service with the British Army in 1998 and has seen deployments in Bosnia, Kosovo and Operation Iraqi Freedom. It is also the primary main battle tank of the Royal Army of Oman. Its L30A1 120mm (4.7-inch) rifled gun is the exception among Western tanks, which usually mount smoothbore weapons. It is capable of firing a variety of ordnance, including HESH (high-explosive squash head) and APFSDS (armour-piercing fin stabilised discarding sabot) rounds. The Challenger 2 has a fine combat record, sustaining damage but withstanding rocket-propelled grenades, anti-tank missiles and IEDs (improvised explosive devices). Its service life is estimated to extend to 2035, and an export variant, the Challenger 2E, has been evaluated in numerous countries.

Below: A Challenger 2 aims its L30A1 120mm main gun at a distant target



STATE-OF-THE-ART SUSPENSION
The Challenger absorbs the rigours of cross-country and road traverse with its second-generation hydropneumatic suspension and hydraulic track tensioner system that support the William Cook Defence hydraulically adjustable double pin tracks.

“THE CHALLENGER 2 HAS A FINE COMBAT RECORD, SUSTAINING DAMAGE BUT WITHSTANDING ROCKET-PROPELLED GRENADES, ANTI-TANK MISSILES, AND IEDS”



TURRET

A solid state electric drive powers the sleek Challenger 2 turret, which is designed with stealth properties to minimise the tank's radar signature. The turret exhibits a 360-degree rotation in a period of nine seconds.

FOUR-MAN CREW INGRESS/EGRESS

The four-man crew is made up of a commander, driver, gunner and loader/operator. Each is equipped with the latest technology for vehicle operation and target acquisition, and enters and exits the tank through secure hatches.

COMMUNICATIONS EQUIPMENT

NBC DEFENCE SYSTEM

A sophisticated defence system against nuclear, biological, and chemical weapons (NBC) is located in the turret bustle of the Challenger 2 main battle tank, while the turret itself is designed to reduce the tank's radar signature.

GUNNER'S PRIMARY SIGHT

ENGINE

Challenger 2 is powered by a 12-cylinder, 1,200-horsepower Perkins Caterpillar diesel engine capable of generating a top speed of 59 km/h on the road and 40 km/h cross-country.

THERMAL IMAGING SENSORS

DRIVE SYSTEM

The 1,200-horsepower Perkins Caterpillar diesel engine drives a power train that includes the David Brown TN54 epicyclic transmission with six forward and two reverse gears that are controlled by the Challenger 2 driver.

SECONDARY ARMAMENT

Challenger 2 is armed with a 7.62mm L94A1 EX-34 chain gun mounted in the turret adjacent to the 120mm main gun and at times a pintle-mounted 7.62mm GPMG L37A2.

SPECIFICATIONS

CREW: 4
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1998
RANGE: 340 MILES (550km)
ARMOUR: CHOBHAM COMPOSITE
ENGINE: 12-CYLINDER, PERKINS CATERPILLAR DIESEL ENGINE
WEAPONS: L30A1 120mm RIFLED TANK GUN; 7.62mm L94A1 EX-34 CHAIN GUN

T-72 MAIN BATTLE TANK

This Soviet-design emerged during the Cold War and continues as a mainstay of many armies around the world

The T-72 main battle tank is the most commonly employed armoured fighting vehicle in the world today – a relic of the Cold War that is still in frontline use in war zones such as Ukraine. Emerging from Soviet design instructions that would leverage existing technology available in the late 1960s and incorporate financially feasible improvements, the T-72 was a concurrent project along with the T-64 main battle tank. While the T-64 was intended for frontline Red Army troops to counter NATO forces in Europe, the T-72 was a cheaper alternative that was intended to equip further Red Army units and Warsaw Pact nations while providing a strong entrée into the global arms export market.

The T-72 was the result of a design competition that pitted Leonard Kartsev and the Uralvagon KB

project based in Nizhny Tagil against the Morozov KB project under Alexander Morozov in Kharkov.

The primary goal of the competition was to develop a cost-efficient replacement for the aging fleet of Communist Bloc T-54 and T-55 main battle tanks that had been in service since the late 1940s. The T-62 and T-64 were initial attempts but success was limited due to high costs, complex attributes and premature entry into production. The shortcomings of the T-62 and T-64 included limited production numbers and some antipathy from fellow Warsaw Pact countries.

The concurrent development of the T-72 was a compromise in cost, firepower and technology. Its longevity in service validates this approach, although the combat effectiveness of the T-72, nicknamed Ural, is a subject of debate.

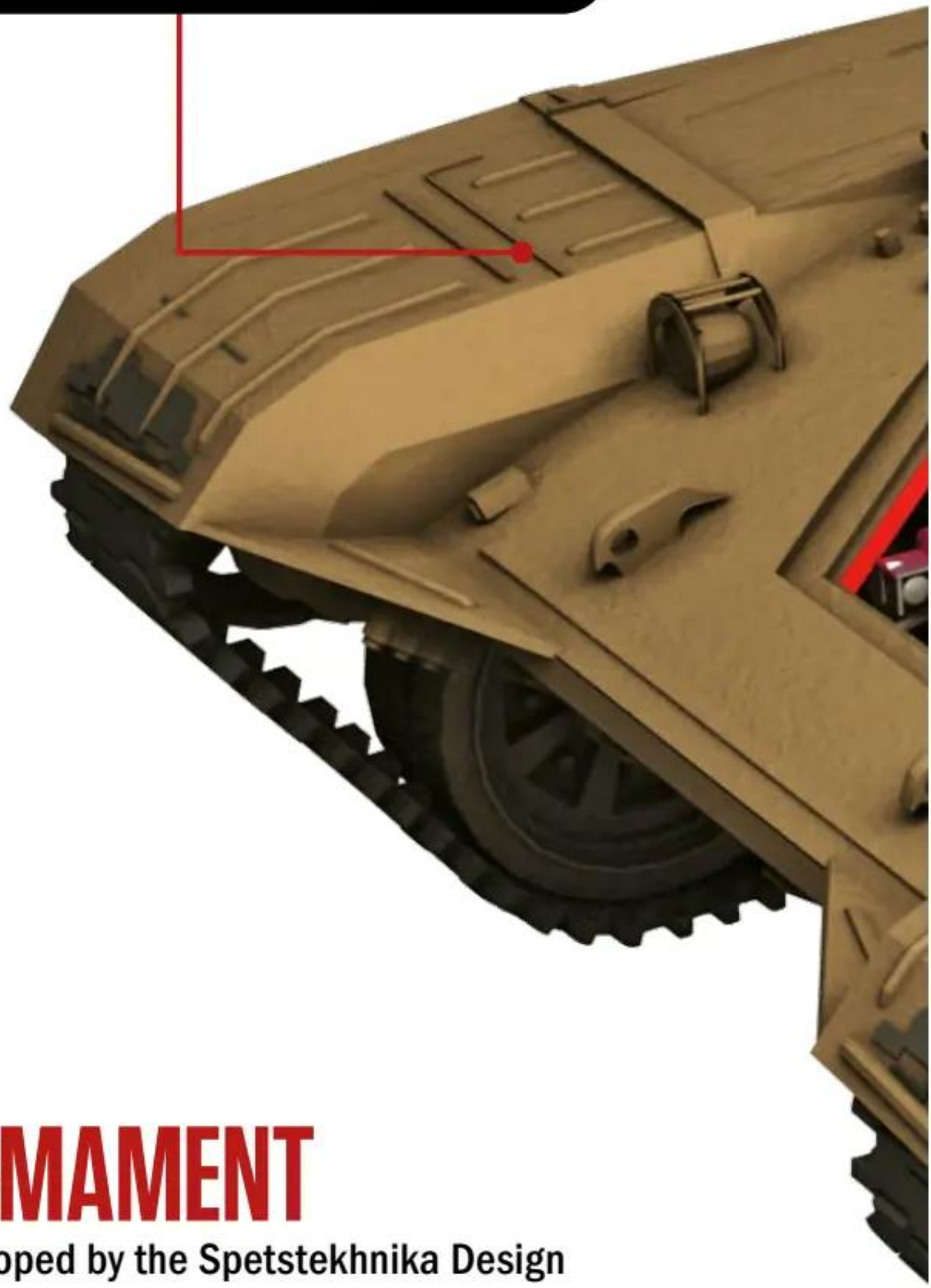
TURRET

The elliptical, ‘frying pan-shaped’ turret has a low silhouette characteristic of previous Soviet tank design. Shells are stored in the turret, making the tank vulnerable if hit.



HULL ARMOUR

The tank’s front glacis is up to 7.9 inch (200mm) thick, while the sides are 2-3.2 inches (50-80mm). Explosive Reactive Armour (ERA) was added to later iterations of the tank.



ARMAMENT

Developed by the Spetstekhnika Design Bureau in Yekaterinburg in the 1960s originally for the T-64, the 2A46M 4.9 inch (125mm) smoothbore cannon has been in service since 1970 and served as the primary weapon of a series of Soviet and Russian main battle tanks. Capable of firing a variety of armour-piercing and high-explosive rounds, the smoothbore was superior to the 4.2 inch (105mm) rifled weapons of Western main battle tanks at the time of its introduction. Its short barrel life was addressed in a subsequent upgrade, while future NATO tanks adopted larger-calibre main weapons to counter the 2A46M. The cannon has also been manufactured in Ukraine and China.



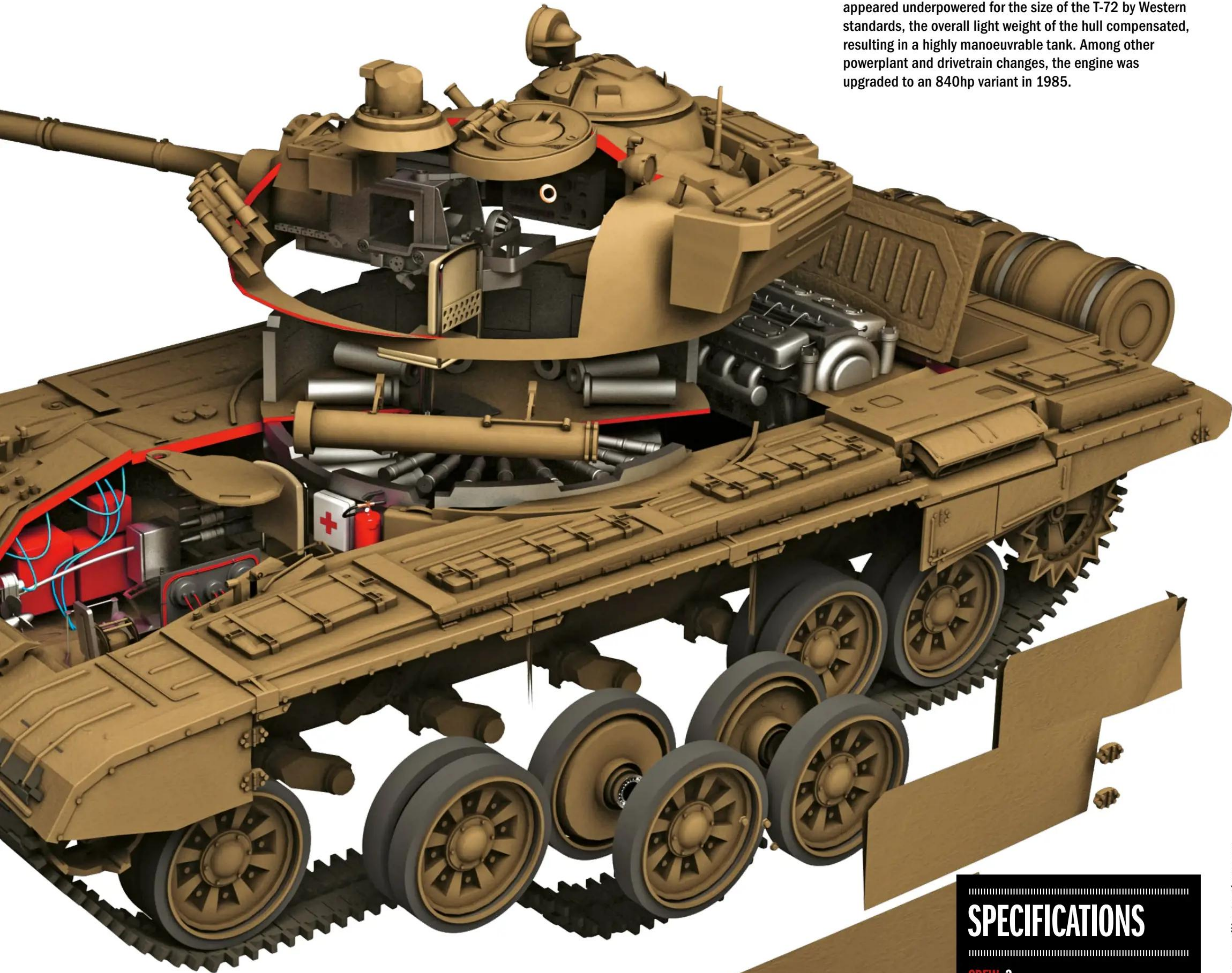
A Ukrainian tank pictured in July 2022 during the war with Russia

CREW COMPARTMENT

Characteristically, the crew compartment of the T-72 main battle tank was not built for comfort. The chassis of the tank was divided into three sections, the crew compartment in the centre. The driver was situated forward with limited visibility through only a single periscope and, unlike Western tank designs that utilised a wheel or yoke, a system of tillers was used to steer. Along with the manual transmission, the driver was fully occupied while the tank was in motion. An automatic loader eliminated the need for a fourth crewman, and the commander was positioned in the turret to the right beneath a rotating cupola, while the gunner was seated in the turret to the left. The maximum height for T-72 crewmen is believed to be 5ft 9 inches (1.75m).

ENGINE

The 780hp, 12-cylinder W-46 diesel engine was much quieter than earlier diesels installed in the T-62, creating lower vibration throughout the vehicle and diminishing smoke output. It was capable of operating on benzene and kerosene when other fuel supplies were unavailable. The W-46 was based on the Second World War-era V-12 engine that powered the T-34 medium tank, which contributed to the interchanging of parts and availability of components for routine maintenance. Although the engine appeared underpowered for the size of the T-72 by Western standards, the overall light weight of the hull compensated, resulting in a highly manoeuvrable tank. Among other powerplant and drivetrain changes, the engine was upgraded to an 840hp variant in 1985.



“THE T-72 WAS A CHEAPER ALTERNATIVE THAT WAS INTENDED TO EQUIP FURTHER RED ARMY UNITS AND WARSAW PACT NATIONS”

SPECIFICATIONS

CREW: 3
COUNTRY OF ORIGIN: SOVIET UNION
COMMISSIONED: 1973
RANGE: 290 MILES (467km)
ARMOUR: UP TO 7.9" (200mm)
ENGINE: 12-CYLINDER W-46 DIESEL
WEAPONS: 125mm SMOOTHBORE 2A46M
CANNON: .50-CAL PINTLE MOUNT & 7.62mm COAXIAL MOUNT MACHINE GUNS

INSIDE A MEDIEVAL CASTLE

Discover the different types of castles that developed across the Middle Ages and how they were used

When you think of the medieval period you likely imagine knights on horseback, jousting contests and, most important of all, a magnificent stone castle. But it wasn't just ruling monarchs who occupied castles, and although these imposing buildings seem very British, they actually first appeared across Central Europe.

In order to understand why castles became so popular in medieval Europe, it's necessary to look at life in the Early Middle Ages. From 800 to 888 CE the Carolingian Empire controlled the majority of Western and Central Europe, just as the Roman Empire had before them. However, when the Carolingian way of life broke down, so too did the central government. Gradually, the nobles began fighting over individual pockets of land. Each lord wanted to regain power and control over his own area, and it wasn't long before violence broke out across the land.

As if this infighting wasn't bad enough, foreign warriors sensed the vulnerability of Europe after the fall of the Carolingian Empire and decided to attack. Viking raiders from Scandinavia made their way to European shores and began pillaging the local villages while the Magyars of historic Hungary began looting raids all across central Europe.

Local lords took it upon themselves to set up their own individual governments, judicial systems and farming, but the continuous warring meant that they needed a way of protecting their personal estates. It was during this period of hostility that the first European castles were born. By using geographical

features of the land such as cliffs, mountains and rivers, buildings could be partially defended – Bran Castle in Transylvania is a prime example of a perfect castle location. However, more was needed if the seats of power were to remain safe.

Ditches were dug, with the soil then used to create a steep hill or 'motte'. Fortified keeps were built on top with a wooden fence erected around the perimeter. The lord and his family could live within the safety of the keep, protecting their personal wealth and ensuring that their government could survive attacks from neighbouring nobility who wanted to increase their own land and power.

William the Conqueror brought the castle to England in 1066. Having won the Battle of Hastings, he proceeded to build motte-and-bailey castles across the UK. Fortresses like Dunluce Castle, precariously perched on the rocky cliffs of Northern Ireland's coastline, took advantage of any natural land formations. It was protected on one side by the sea while the villagers settled outside

the castle gate. If there was no geographical advantage, an artificial hill was created, such as the motte built in the centre of Windsor Castle, known as the Middle Ward.

The castle became a reward offered by the monarch to the nobles in return for their support. With the ever-present threat of a civil war, the king required reliable allies across the country who could quell unrest as it broke out among the people. These later 'gifted' castles were far more luxurious, offering the nobility a beautiful home as well as a secure place to hold administrative meetings.

As time progressed and weaponry improved, castles needed to change their basic design and the materials used. Originally, windows were closed with wooden shutters, but these were later replaced with stone slits known as 'arrow loops' that made it very difficult for enemies to shoot their arrows through.

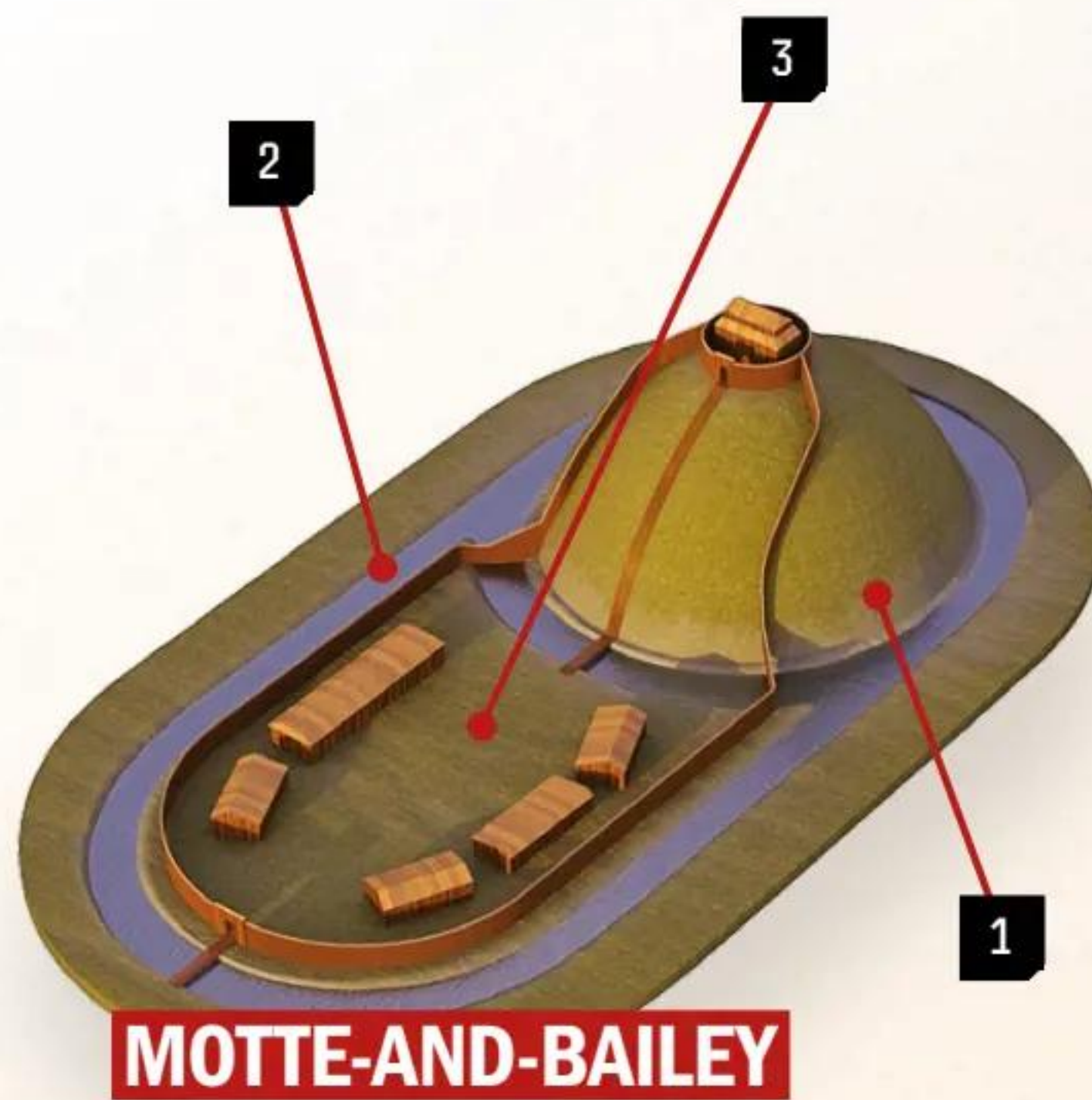
Stone walls became thicker and higher, with crenulations that allowed guards to both loose their arrows and to shield themselves from and returning missiles. However, with the emergence of the cannon even the fortified concentric castles crumbled, and new designs of fortresses were built to withstand the immense firepower of the gunpowder era.

**"THE CASTLE BECAME A
REWARD OFFERED BY THE
MONARCH TO THE
NOBLES IN RETURN FOR
THEIR SUPPORT"**

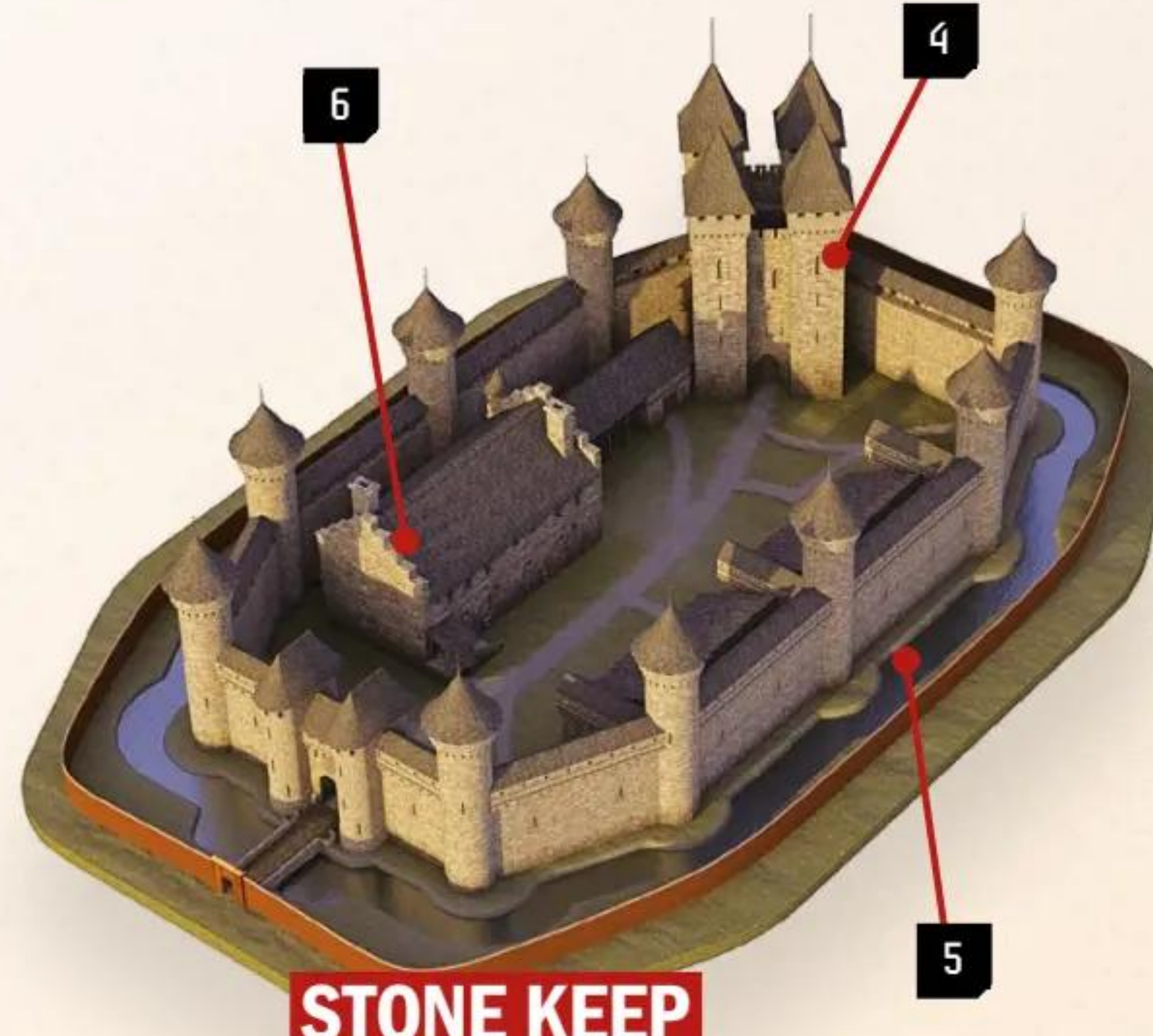


CASTLE CHARACTERISTICS

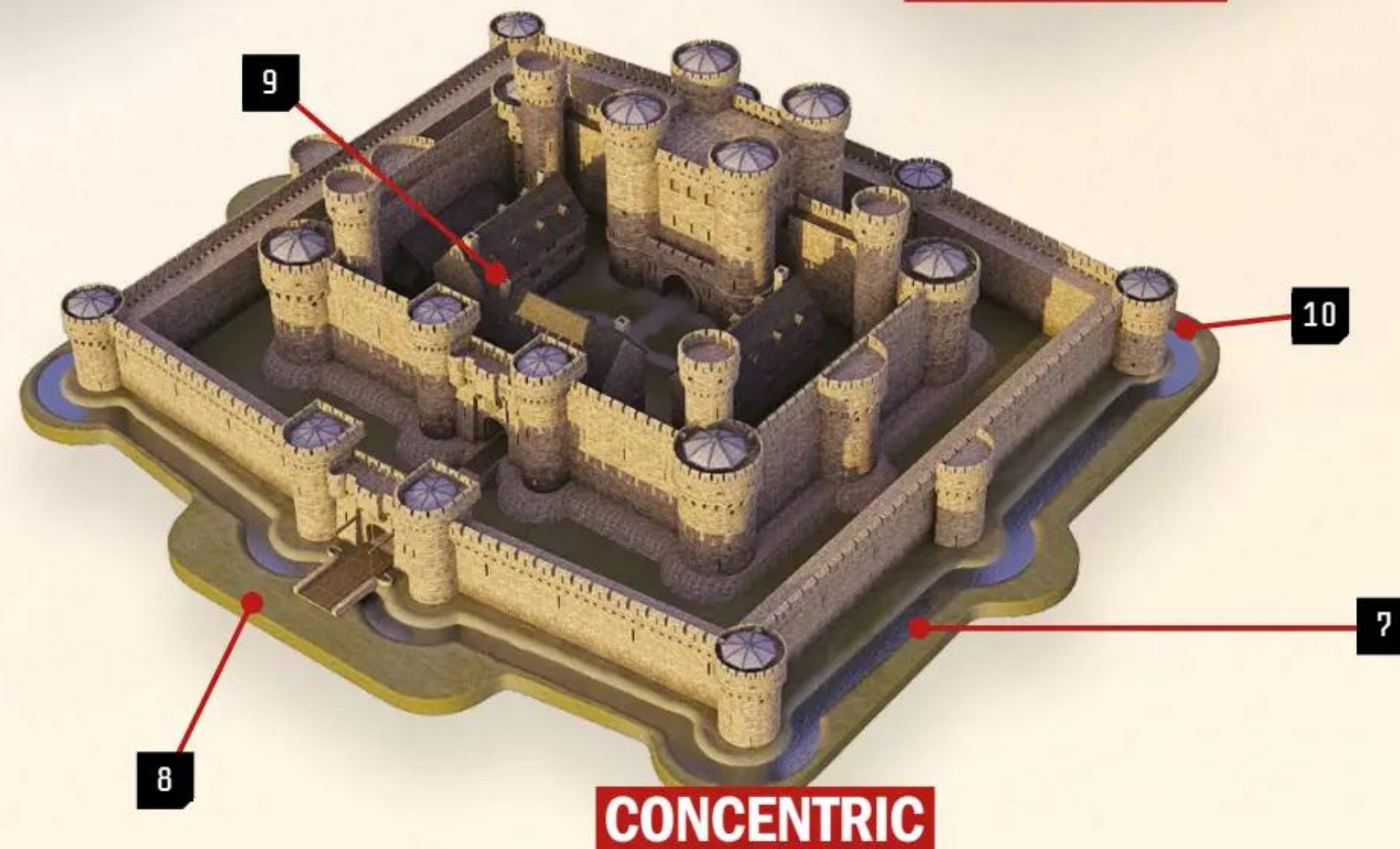
Medieval castles came in three main designs, each one adopting new defences



MOTTE-AND-BAILEY



STONE KEEP



CONCENTRIC

1 MOTTE

The earthen mound could be up to 30 metres high. Steep sides called the 'scarp' made it difficult for intruders to climb up.

2 WOODEN PALISADE

This surrounded the bailey to keep the enemy out and was used in conjunction with a ditch that ran around its edge.

3 BAILEY

This courtyard contained domestic buildings such as the kitchens and stables and areas where the livestock could graze.

4 STONE KEEP

Stronger than a wooden tower, the stone keep was the improved living quarters of the lord and the last line of defence.

5 MOAT

A wide, deep ditch was dug around the castle and filled with nearby water to prevent intruders from reaching the walls.

6 GREAT HALL

Here the lord of the castle could hold banquets, reinforcing his status in the area.

7 CURTAIN WALLS

The double layer of protective walls had to be thick enough to withstand bombardment and too high for attackers to climb over.

8 THE GATEHOUSES

These entry points were protected by a metal grill, or 'portcullis'. Boiling oil was poured onto the enemy through 'murder holes' made in the ceiling.

9 DOMESTIC BUILDINGS

The kitchens, stables, a brewery and the water well were kept safe within the inner bailey.

10 TOWERS

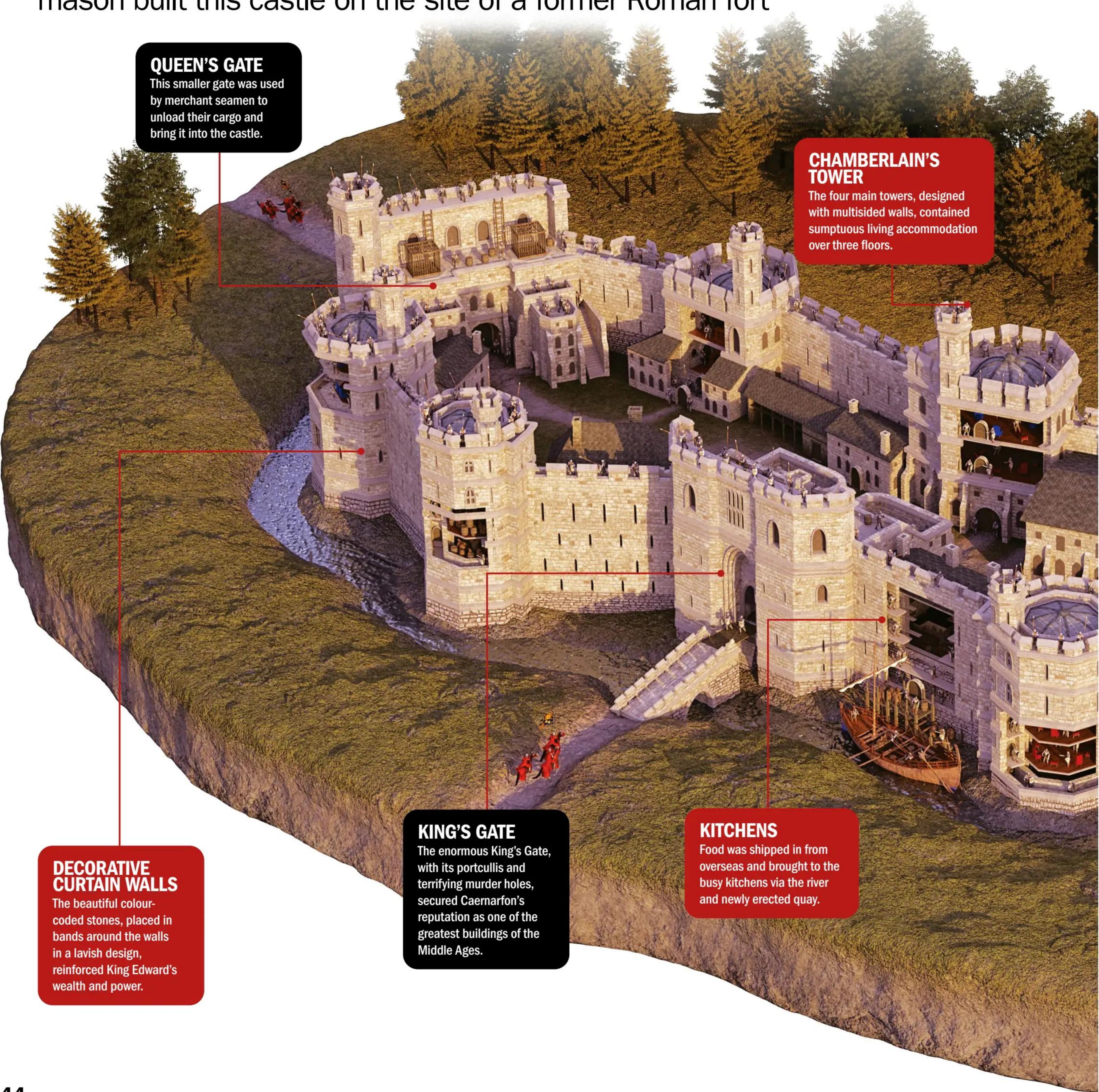
Circular towers were strategically placed around the curtain walls to give archers a 360-degree view.



Medieval

CAERNARFON CASTLE

Designed to quash the warring Welsh princes, King Edward I's master mason built this castle on the site of a former Roman fort



QUEEN'S GATE

This smaller gate was used by merchant seamen to unload their cargo and bring it into the castle.

CHAMBERLAIN'S TOWER

The four main towers, designed with multisided walls, contained sumptuous living accommodation over three floors.

DECORATIVE CURTAIN WALLS

The beautiful colour-coded stones, placed in bands around the walls in a lavish design, reinforced King Edward's wealth and power.

KING'S GATE

The enormous King's Gate, with its portcullis and terrifying murder holes, secured Caernarfon's reputation as one of the greatest buildings of the Middle Ages.

KITCHENS

Food was shipped in from overseas and brought to the busy kitchens via the river and newly erected quay.

CASTLES BEYOND EUROPE

Just as European castles were designed to act as both a fortress and a luxurious home, so too were the remarkable strongholds built further afield. Each country relied upon the natural contours of the area, such as a hill or a cliff, for security and utilised local resources to build their structure. Japanese castles were predominantly built of wood and stone and were created not only to safeguard, but also to show off the wealth of the feudal lords. The Citadel of Aleppo in Syria was made of limestone and was similarly designed to protect and impress. The medieval castle Fasil Ghebbi in Ethiopia included 12 gated towers to protect the royal family. It was the first two-storey building in the country.



GREAT HALL

There were two halls situated inside the Inner Bailey. The Great Hall was used by the king when hosting banquets.

QUEEN'S TOWER

In 1284, Queen Eleanor gave birth to the future King Edward II in the plush rooms situated inside the Queen's Tower.

EAGLE TOWER

This ten-sided tower measured over ten metres across and was adorned with stone eagles, reflecting the site of the Roman fort.

IDEAL LOCATION

Caernarfon Castle, built at the mouth of the River Seiont, allowed ships to bring supplies and timber right to the door.

DITCH

A deep ditch filled with water separated the castle from the town, acting as a protective moat.

TOWN WALLS (NOT SEEN)

At 2,400 foot (734 metres) long, the town walls cost £3,500 (\$4,300) to build at the time.

WATER GATE

During the Welsh Revolt of 1294, the dissenting locals breached a number of the fortified gates.

Early Modern

HIMEJI CASTLE

This fortress has witnessed centuries of Japanese history

Himeji Castle is a Japanese National Treasure as well as a UNESCO World Heritage Site. It's also one of Japan's 12 original castles, with the current complex completed in 1618 and widely considered to be a fine example of early 17th century Japanese castle architecture.

Ikeda Terumasa was the brains behind what we see today. As the shogun of west Japan and the son-in-law of the Japanese warrior and statesman Tokugawa Ieyasu, he was handed the castle in 1600 as a reward for his support in the Battle of Sekigahara. Within a year, he'd ordered its demolition and a new structure was commissioned to take its place.

By 1609, the new castle was completed, although additions were made towards the end of the following decade. The end result was on a much grander scale than the 16th century structure it had replaced. It was also a far cry from the fortified building that originally occupied the site in 1333, for here was a complex of 83 buildings (one of which towered over the rest), connected by winding paths and constructed with defence in mind.

There were three moats, walls that were up to 26 metres high and many heavily fortified gates in unexpected places that would slow any advancing army. Concerted attempts were also made to ensure that the enemy would have to twist and turn if they were to make their way towards the main tower, with the steep, narrow paths being deliberately confusing.

As much attention was paid to the castle's elegantly balanced appearance, too. The multiple roof layers were a mix of the curved and the triangular, and the protective white plaster adorning the walls ensured the buildings stood proud. Even so, the castle has not always been appreciated and in the late-19th century it was on the verge of being demolished and replaced with army barracks.

It has survived earthquakes and the Second World War, however, and the castle remains intact. Today it's Japan's most-visited castle and a 2015 renovation means it's back to its best.

"IT HAS SURVIVED EARTHQUAKES AND THE SECOND WORLD WAR"

MAIN KEEP

The core part of the castle became the main keep (or tenshu), dominated by a tower 46 metres tall. Although looking like a five-storey building from the outside, that's an illusion of sorts – it was built with six floors and a basement, with what looks like the fourth floor from the bottom having an extra level above it. This would help to confuse any potential enemies.

WHITE PLASTER

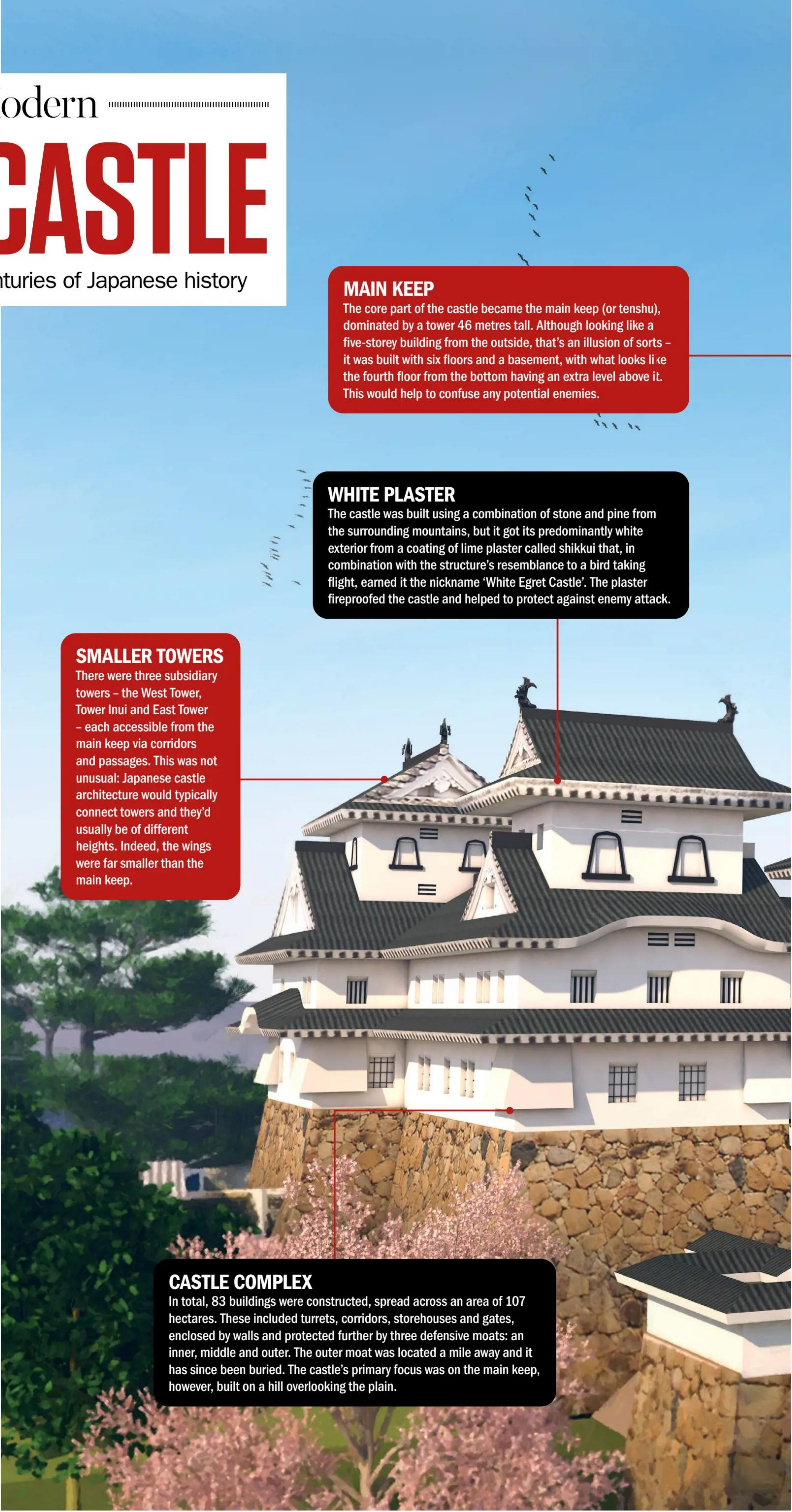
The castle was built using a combination of stone and pine from the surrounding mountains, but it got its predominantly white exterior from a coating of lime plaster called shikkui that, in combination with the structure's resemblance to a bird taking flight, earned it the nickname 'White Egret Castle'. The plaster fireproofed the castle and helped to protect against enemy attack.

SMALLER TOWERS

There were three subsidiary towers – the West Tower, Tower Inui and East Tower – each accessible from the main keep via corridors and passages. This was not unusual: Japanese castle architecture would typically connect towers and they'd usually be of different heights. Indeed, the wings were far smaller than the main keep.

CASTLE COMPLEX

In total, 83 buildings were constructed, spread across an area of 107 hectares. These included turrets, corridors, storehouses and gates, enclosed by walls and protected further by three defensive moats: an inner, middle and outer. The outer moat was located a mile away and it has since been buried. The castle's primary focus was on the main keep, however, built on a hill overlooking the plain.



FISH-SHAPED ORNAMENTS

Eleven statues of a shachihoko – a folklore animal that has a carp's body and a tiger's head – were placed on top of the main keep's distinctive hip-and-gabled roofs (irimoya-hafu), proving as strikingly decorative as the building's patterned dormer gables (chidori-hafu). They served a purpose, in theory at least, since there was a strong ancient belief that the ornaments would protect the castle from fire by spouting jets of water from their mouths.

WOODEN INTERIORS

The first floor provided the largest space and contained more than 300 tatami mats, as well as racks for firearms, spears, gunpowder bags and fuses. Further up, the rooms grew ever smaller and there were many hidden spaces, including a hiding place on the third floor from which enemies could be ambushed should they successfully get inside.

ON THE LOOKOUT

Holes of various shapes were created in the thick castle walls and on the towers so the defenders could keep lookout and fire at their enemies. They would be large enough to shoot arrows out of, but because they were bigger on the inside than on the outside, enemies were less likely to get a successful shot themselves.

DEFENSIVE DROPS

To guard against potential attack (luckily this never happened), defenders would have dropped stones onto their enemies below through a series of slim openings positioned at the north and south windows on the third floor of the main keep, as well as on the fourth floor. When they were not in use, the holes were covered internally by long wooden planks.

CREATING STRONG FOUNDATIONS

Two huge pillars were placed inside the main keep for support. One to the east was originally made from a single fir tree. The other, to the west, was made of a 26-metre Japanese cypress taken from the Kiso Mountains. They were created to run from the basement to the ceiling of the near-windowless fifth floor. The sixth floor, incidentally, offered panoramic views and was the location of the Osakabe Shrine.

THE INNER COURT

A consequence of connecting the towers was the formation of an inner court. A kitchen was located there, enabling the inhabitants to stockpile and prepare food should invaders seek to starve them out. There was also courtyard in the southeast corner known as the Harakiri Maru, which was a space for ritual suicide.

FOKKER EINDECKER

This fighter aircraft made history with the combat deployment of its new, deadly, synchronised firing system

Anthony Fokker modified the French Morane-Saulnier H as a single-seat light reconnaissance aircraft, designated the M.5. First flown in 1913, the M.5 became the prototype of Fokker's famed Eindecker fighter. Improvements over the French design included a lengthened fuselage, with a chrome-molybdenum steel tubing covered by fabric rather than a wooden frame.

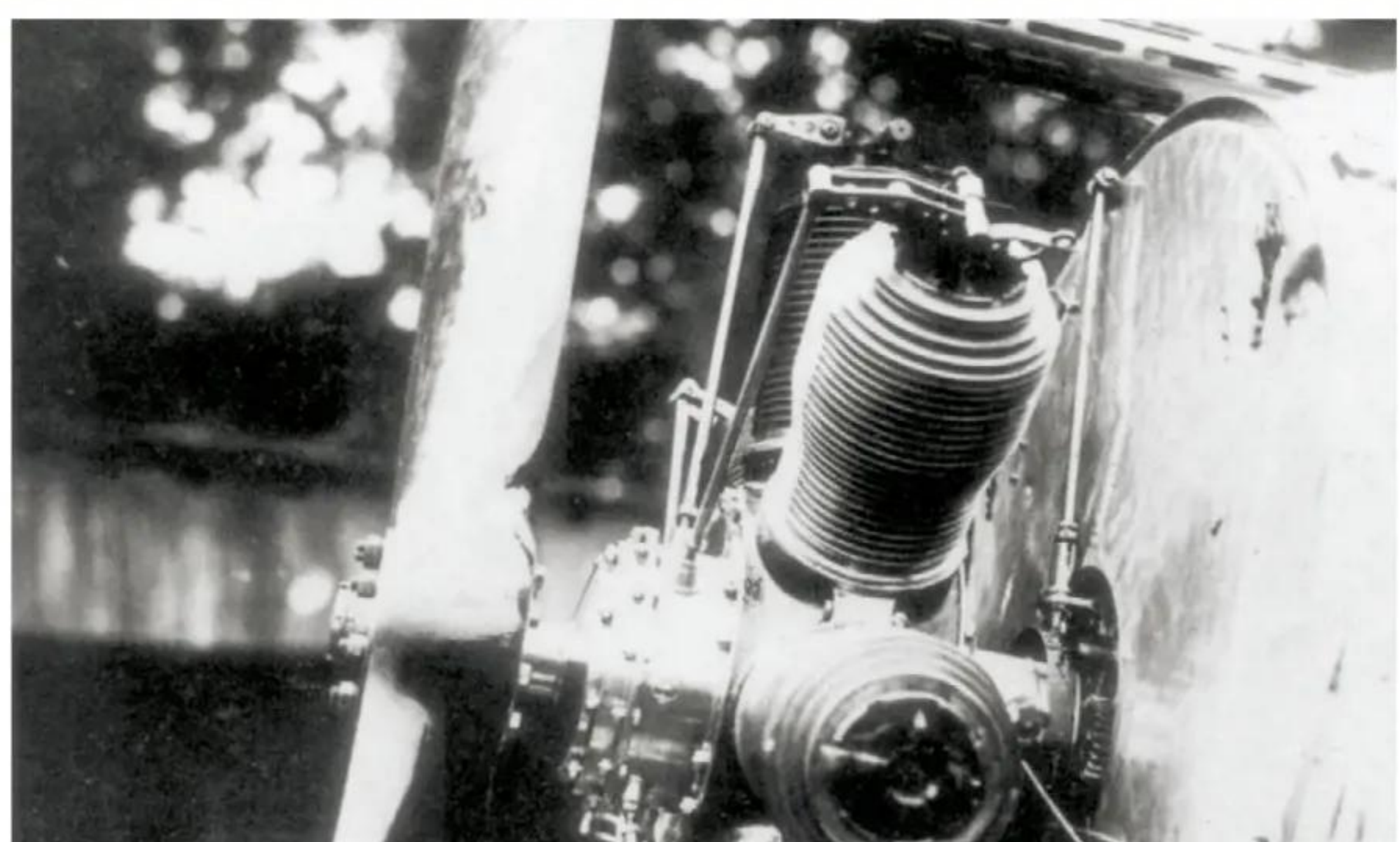
The rudder was reshaped to resemble a comma, and the fixed undercarriage and landing gear were constructed with the bracing pylons below the wings. The primary production E.III variant was improved over earlier designs, with its larger horseshoe cowling and wings with narrower chord, or distance from the leading to trailing edge. Sheet metal surfaces were distinctive with 'engine turning', the appearance of machined geometric patterns.

SYNCHRONISATION SYSTEM

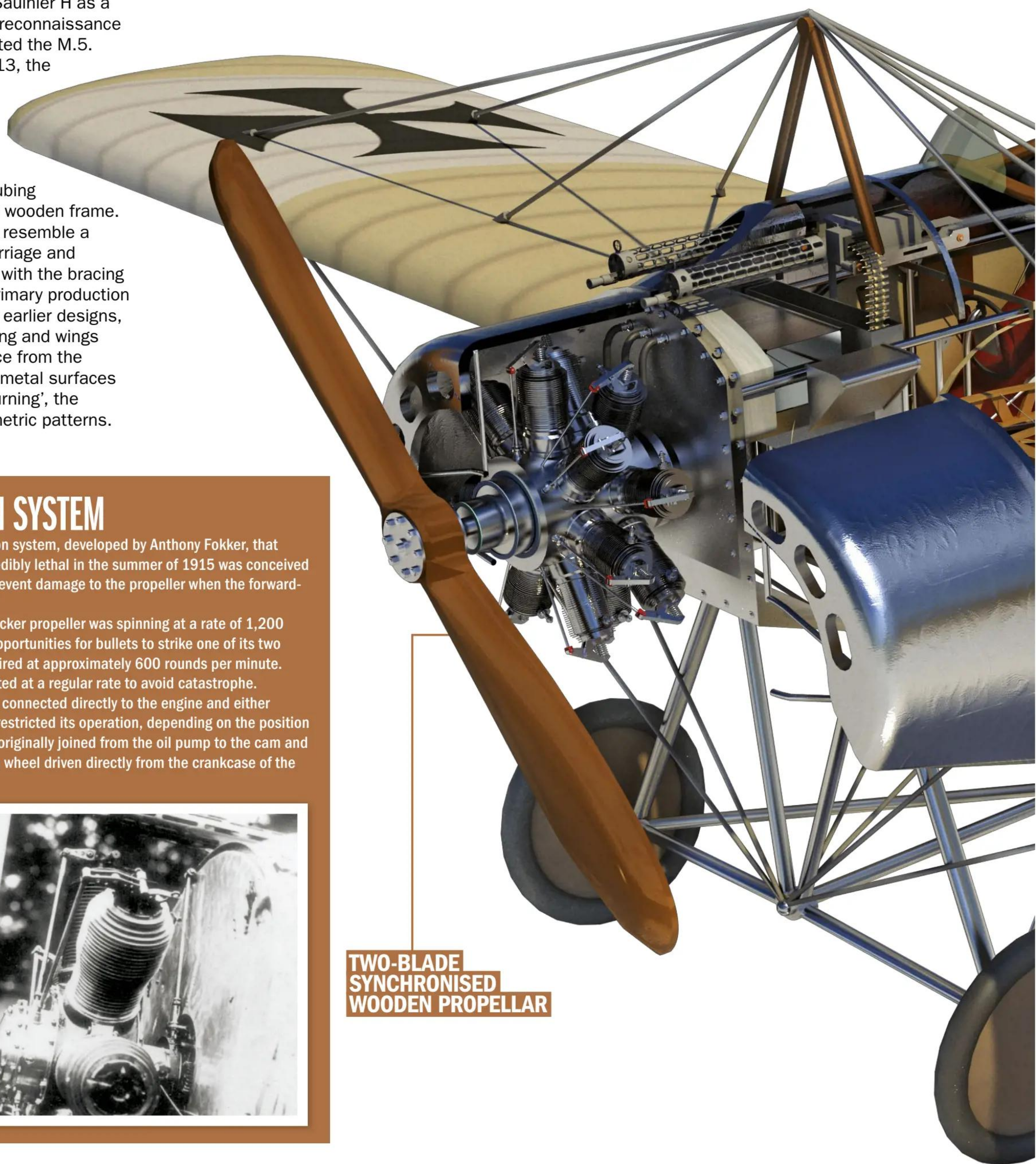
It was the innovative synchronisation system, developed by Anthony Fokker, that made the Eindecker fighter so incredibly lethal in the summer of 1915 was conceived as an interrupter gear that could prevent damage to the propeller when the forward-firing machine gun fired through it.

Fokker calculated that the Eindecker propeller was spinning at a rate of 1,200 turns per minute, totalling 2,400 opportunities for bullets to strike one of its two blades. The 7.92mm machine gun fired at approximately 600 rounds per minute. Therefore, its fire could be interrupted at a regular rate to avoid catastrophe.

Fokker designed a cam that was connected directly to the engine and either allowed the machine gun to fire or restricted its operation, depending on the position of the propeller blade. A shaft was originally joined from the oil pump to the cam and was then replaced with a large cam wheel driven directly from the crankcase of the rotary engine.



**TWO-BLADE
SYNCHRONISED
WOODEN PROPELLAR**



SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: GERMANY
COMMISSIONED: 1915
RANGE: 123 MILES (198km)
TOP SPEED: 87mph (40km/h)
ENGINE: OBERURSEL U.1 9-CYLINDER,
 100-HORSEPOWER RADIAL
WEAPON: 1x OR 2x 7.92mm MACHINE GUNS

ARMAMENT

The Fokker Eindecker series was armed with a succession of 7.92mm machine guns, either the Maschinengewehr MG 08, Parabellum MG 14 or Spandau LMG 08. These were typically single mounts, affixed to the engine cowling, offset to the right forward of the cockpit and positioned for synchronised fire through the arc of the propeller. Experiments were conducted with twin mounts, and famed ace Max Immelmann briefly utilised a configuration of three machine guns. The Maschinengewehr guns were adapted from infantry weapons, while the Parabellum was purpose-built for aircraft. Each was belt-fed and capable of a sustained rate of fire of about 600 rounds per minute.

RUDDER

Among the improvements Anthony Fokker made to the original French Morane-Saulnier design was a comma-shaped rudder that improved the pilot's overall control of an inherently unstable aircraft.

CHROME AND MOLYBDENUM FRAME

SHEET METAL SURFACES

Sheet metal surfaces on the Fokker Eindecker were distinctive in appearance, with the addition of machined 'turning' that resulted in the appearance of geometric patterns in the metal itself.

ENGINE

The early Fokker Eindecker, designated E.I, mounted the seven-cylinder, 80-horsepower Oberursel U.0 rotary petrol engine, a license-built copy of the French-designed Gnome Lambda or Delta rotary engines that the fledgling German aircraft industry had been producing before the outbreak of World War I. The later E.II and E.III Eindeckers were powered by the Oberursel U.1 nine-cylinder, 100-horsepower rotary engine, while the E.IV was fitted with the 14-cylinder Oberursel U.III. The engines were air-cooled and reliable. However, although the plane was light, it could achieve a maximum speed of only 87 miles (140 kilometres) per hour with the larger powerplant.

**"THE INNOVATIVE
 SYNCHRONISATION SYSTEM,
 DEVELOPED BY ANTHONY
 FOKKER, MADE THE EINDECKER
 FIGHTER INCREDIBLY LETHAL"**

VICKERS VIMY

This RAF heavy bomber paved the way for peacetime travel

The Vimy was a heavy bomber commissioned in 1917 to conduct a bombing campaign against Germany. The first Vimy flew in November 1917 and a series of different marques were tested (mostly differing in engine types) until the Mk. IV, powered by Rolls Royce Eagles, was settled on as the production model. Deliveries began in October 1918 with a single example being sent to France for operational evaluation. The war ended the following month and deliveries slowed. The type was then settled on as the RAF's main post-war heavy bomber and it finally entered frontline service in July 1919.

Although many of the original orders were cancelled around 240 were built and served in the UK and Middle East. After leaving frontline service in 1929 the type remained in use for flying training and parachute training (with the parachutists clinging to the wing struts!) until just before the Second World War.

“THE FIRST VIMY FLEW IN NOVEMBER 1917 AND A SERIES OF DIFFERENT MARQUES WERE TESTED UNTIL THE MK. IV, POWERED BY ROLLS ROYCE EAGLES, WAS SETTLED ON”



This view of a Vimy shows the Scarf Rings in the forward and rear turrets. The guns were rarely carried in peacetime

OCTAGONAL ENGINES

The nacelles holding the engine were a distinctive octagonal shape and were suspended from struts between the wings.

ON THE NOSE

The wooden nose skid helped prevent the aircraft tipping on landing, a common danger with First World War era aircraft.

COCKPIT

The Vimy's cockpit was cramped with a pilot and co-pilot crammed in beside each other. The pilot needed both hands on the control wheel, using all their strength to haul the heavy aircraft around the sky. The co-pilot operated the rest of the controls. Their open cockpit was surprisingly sheltered with the nose acting as a windbreak, although the closeness of the propellers (within arm's reach) could lead to the cockpit being showered in water. Some of the engine gauges were on the sides of the engines.



LIGHT TO WORK BY

The glass panels in the fuselage were to provide light while the gunner managed his magazines, or moved his gun to the lower position.

ENGINE

The Rolls Royce Eagle was that company's first aero engine and as such was the first in an illustrious line. First designed in 1914 it was a 12 cylinder in-line engine that went through extensive development during the war until the Mk. VIII version for the Vimy and was rated at 360hp (270kW). The Mk. VIII was the most produced Eagle variant (just over 3,300 out of a total of 4,681 Eagle engines), and was famed for its high-quality engineering and reliability.

ARMAMENT

The Vimy's bomb load was two 230lb (104kg) and eighteen 112lb (51kg) bombs, split across an internal bay between the wings behind the main spar, and external racks under the inner lower wings. Plans were also made to equip them with two torpedoes. The aircraft had two 0.303" (7.7mm) Lewis machine guns on Scarff Rings, one in the nose and one midway down the fuselage. A hatch in the bottom of the fuselage could theoretically be used to shift the upper gun down to provide protection below.

SPECIFICATIONS

CREW: 3
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1917
RANGE: 900 MILES (1,400km)
TOP SPEED: 103mph (166 km/h)
ENGINE: 2x ROLLS ROYCE EAGLE VIII
PAYLOAD: 2x 230lb (104kg) AND 18x 112lb (51kg) BOMBS
WEAPONS: 2x 0.303" (7.7mm) LEWIS MACHINE GUNS

Second World War

SUPERMARINE SPITFIRE

Arguably the most iconic fighter aircraft of the Second World War, the RAF Spitfire to this day is championed for its prowess, grace and versatility

Designed in the technologically fervent and innovative melting pot of the Second World War, the Supermarine Spitfire became the fighter plane of the times. With its simple lines, elegant frame and superb aerodynamics, the Spitfire was to live on in the minds of generations during the war and for decades to come.

The Spitfire was the brainchild of aeronautical engineer Reginald Mitchell, who led a dedicated and talented team of designers. Originally planned as a short-range air-defence fighter, the Spitfire was built for speed and agility, traits that it was to need in the explosive dogfights it was to partake in as it met enemy fighters and bombers. Building a fighter plane, though, is more complex than listing desirable traits however, and the Spitfire's construction is a balletic series of compromises between weight, aerodynamics and firepower.

The frame of a Spitfire with its elliptical wings is one of its most defining characteristics, casting a distinctive silhouette against the sky. The ellipse shaping was used to minimise drag while having the necessary thickness to accommodate the retracted undercarriages and the guns required for self defence. A simple compromise that had the resulting benefit of having an incredibly individual shape. In contrast, the airframe – which was influenced by exciting new advances in all metal, low-wing plane construction – was a complex and well-balanced amalgamation of a streamlined semi-single piece of aluminium alloy and a fully enclosed cockpit. This allowed unrivalled responsiveness and ease of flight, making the Spitfire a favourite for pilots.

PROPELLER

Original Spitfires had wooden propellers, these were later replaced with variable-pitch propellers, and more blades were added as horsepower increased.

Arguably, the other most defining and success-inducing element of the Spitfire was its engine, which took on the form of the Rolls-Royce Merlin and Griffon engines. Planned by a board of directors at Rolls-Royce who realised that their current Vee-12 engine was topping out at 700hp and that a more powerful variant would be needed, first the Merlin and later the Griffon engines were designed. The Merlin at first delivered 790hp, short of the 1,000hp goal set in its design brief, however this was to increase to 975hp in a few years. The Griffon then built upon the success of the Merlin, delivering at the climax of its advancement a whopping 2,035hp. These engines were to prove tantamount to the airframe and wing designs in the dominance of the Spitfire.

Despite its origins lying in short-range home defence, the Spitfire was to prove so versatile and successful that it was quickly adapted for a wide variety of military purposes. Many variants were created, including designs tailored for reconnaissance, bombing runs, high-altitude interception and general fighter-bomber operations. The most notable derivative, however, was the multi-variant Seafire, specially

ROLLS-ROYCE V-12 ENGINE

The Spitfire utilised two variant of Rolls-Royce engine during its production life span, the 27-litre Merlin and the 36.7-litre Griffon.

designed for operation on aircraft carriers with the added ability to double-fold its wings for ease of storage.

Considering the place in history that the Spitfire holds – a fighter-bomber aircraft that bridged the gap between the age of the propeller engine to that of the jet – the fact that they are still collected (with an average cost of £1.4 million) and flown today is unsurprising. The Spitfire is a timeless piece of engineering that shows some of the most creative and advanced efforts in military history.

FULLY ENCLOSED COCKPIT

The benefits of a fully enclosed cockpit were numerous, most notably though it improved the Spitfire's aerodynamics.



FUSELAGE

The fuselage of the Spitfire was constructed from toughened aluminium alloy, composing of 19 individual frames.

ELLIPTICAL WING

The elliptical wing of the Spitfire is a defining design characteristic, functional to the extreme and aesthetically pleasing to the eye.

SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1936
RANGE: 400 MILES (644km)
TOP SPEED: 450mph (724km/h)
ENGINE: ROLLS-ROYCE V-12
WEAPONS: .303-INCH BROWNING MACHINE GUNS; 20mm HISPANO CANNONS

AIRFRAME

The aircraft's airframe was an amalgamation of a streamlined semi-single piece of aluminium alloy with an enclosed cockpit, allowing increased responsiveness and ease of flight.

UNDERCARRIAGE

The Spitfire's undercarriage was fully retractable, a refinement that was not commonplace in earlier aircraft.

GUN-EMPLACEMENT

The original armament of the Spitfire comprised of eight .303-inch Browning machine guns, each with 300 rounds of ammunition.



MITSUBISHI A6M 'ZERO'

Japan's legendary carrier fighter distinguished itself in WWII's Pacific theatre

COCKPIT

The Mitsubishi A6M had a fully enclosed cockpit that followed the general pattern of most contemporary fighters. A main instrument panel with essential flight indicators in front of the pilot had the gunsight above, flanked on either side by the butts of the machine guns. The panel on the left side of the cockpit contained the throttles and fuel tank selectors. On the right were the radio and its controls, including a direction finding set for navigation at sea, along with the undercarriage and tail-hook switches.

LIMITED PUNCH

The Zero's light construction left it unable to carry heavy armament, although later models had a further machine-gun added to each wing.

A low-wing cantilever design, the Zero was designed for aircraft carrier operations with a short wingspan and wide, sturdy undercarriage. With light construction and a low-wing loading, it was highly manoeuvrable except at high speeds, and had a very low stalling speed. Everything was done to save weight, with no armour or self-sealing fuel tanks, making the aircraft long-ranged, fast, manoeuvrable but desperately vulnerable to enemy fire. Most of the aircraft was built from an aluminium alloy formed to a secret formula called 'extra super duralumin'.

IMPRESSIVE FUEL TANKS

Between the main fuel tank behind the engine, the tanks in either wing stub, and the optional drop tank, the Zero had a much longer range than other contemporary fighters.

"THE ZERO WAS DESIGNED FOR AIRCRAFT CARRIER OPERATIONS WITH A SHORT WINGSPAN AND WIDE, STURDY UNDERCARRIAGE"

ENGINE

Made by the Nakajima Aircraft Company, the Sakae ('Prosperity') was a twin-row 14-cylinder air cooled radial engine. The type was used by the Imperial Japanese Navy Air Service as the NK1, with four models (the Zero used the 'C') used on a range of aircraft. The Imperial Japanese Army Air Force also used it for single and twin-engine aircraft as the 'Ha' series. It was rated at 940hp (700 kW) for take-off and 950hp (710 kW) at an operational height of 13,800ft(4,200m)

ARMAMENT

The Zero was armed with two 0.303-inch (7.7mm) Type 97 machine guns in the cowling over the engine, firing through the propeller and supplied with 500 rounds per gun, and two 0.787-inch (20mm) Type 99-1 cannon in the wings, each with 60 rounds (increased to 100 rounds from 1941). The armament was relatively light, and proved inadequate against later American carrier fighters. A small load of two 130lb (60kg) bombs could be carried, or a fixed 550lb (250kg) bomb for kamikaze attacks late in the war.

SPECIFICATIONS

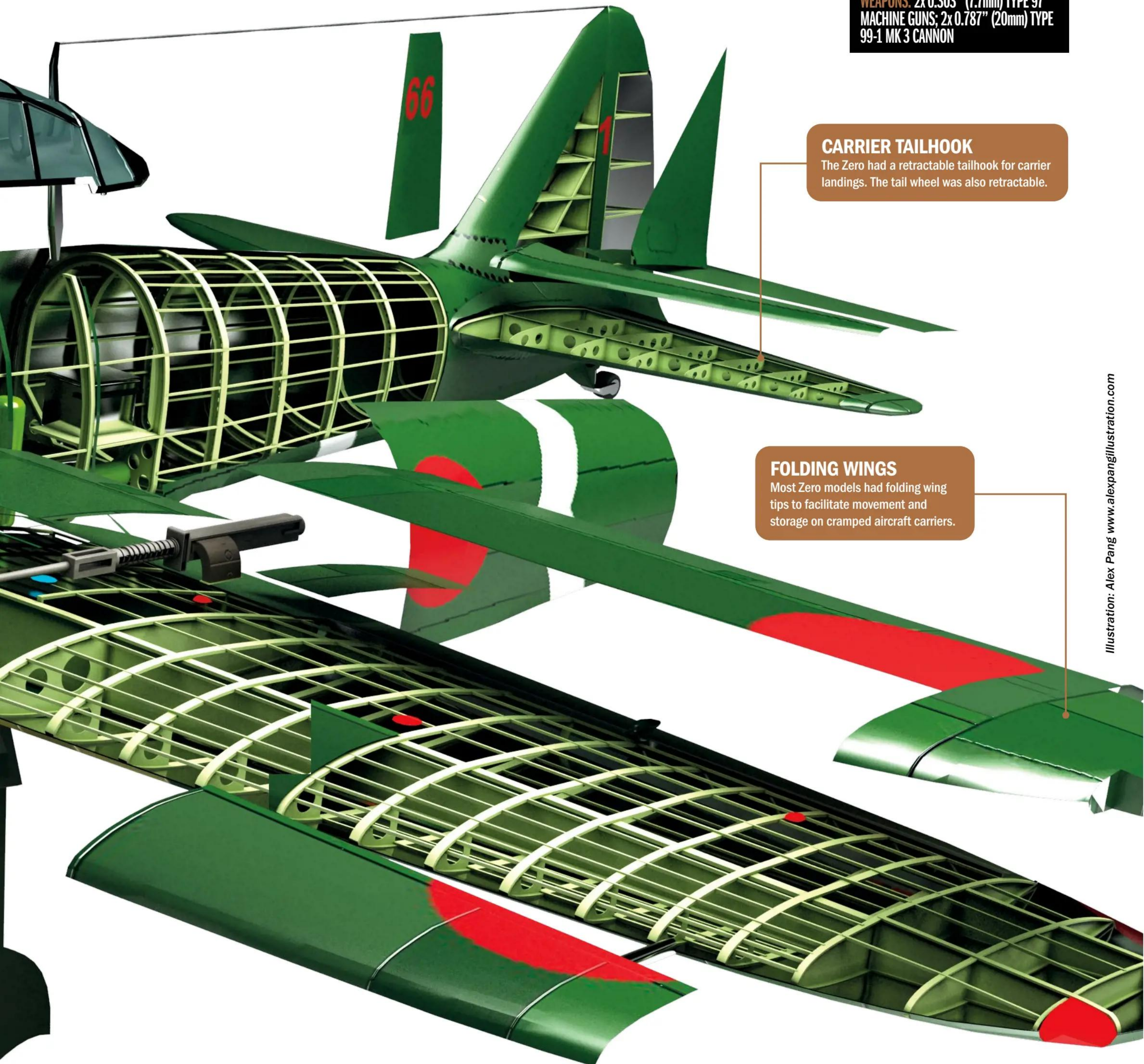
CREW: 1
COUNTRY OF ORIGIN: IMPERIAL JAPAN
COMMISSIONED: 1937
RANGE: 1,160 MILES (1,870km)
TOP SPEED: 351mph (565km/h)
ENGINE: NAKAJIMA NK1C SAKAE-12
 14-CYLINDER AIR COOLED RADIAL
WEAPONS: 2x 0.303" (7.7mm) TYPE 97
 MACHINE GUNS; 2x 0.787" (20mm) TYPE
 99-1 MK 3 CANNON

CARRIER TAILHOOK

The Zero had a retractable tailhook for carrier landings. The tail wheel was also retractable.

FOLDING WINGS

Most Zero models had folding wing tips to facilitate movement and storage on cramped aircraft carriers.

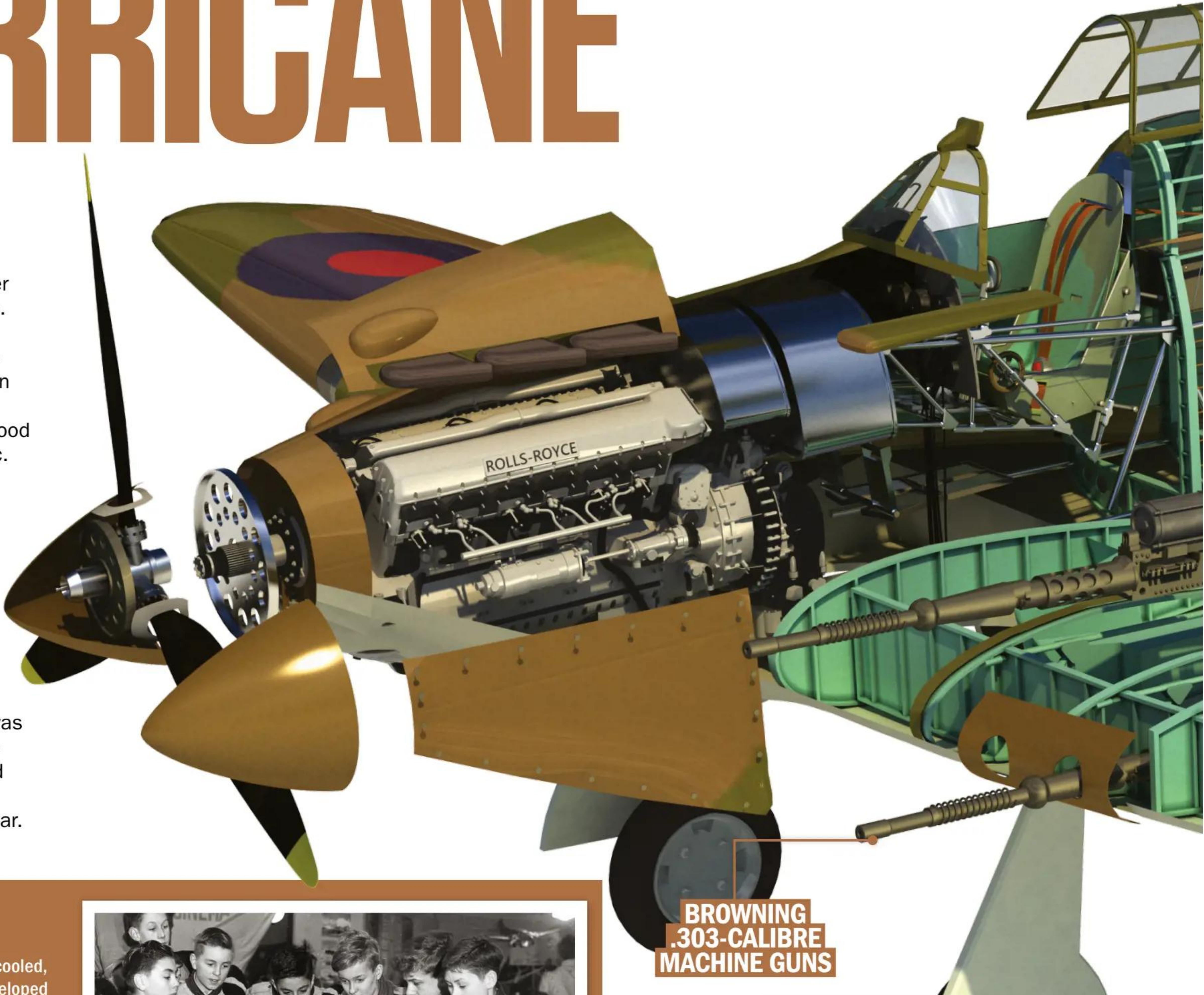


Second World War

HAWKER HURRICANE

This aircraft bore the brunt of the Luftwaffe onslaught during the early days of World War II

Aircraft designer Sir Sydney Camm developed the low-wing cantilever Hawker Hurricane. Early production aircraft wings were covered in fabric and were later replaced with stressed-skin metal wings, while the fuselage was of tubular duralumin and wood construction covered with fabric. This design aspect, at first an expedient to get the fighter into service, remained unchanged throughout production. The Hurricane was relatively heavy – a sturdy and stable gun platform. However, it was slower than the Spitfire and the German Messerschmitt Me 109. Its service ceiling of 34,000 feet was lower than the Me 109, and the pilot had to contend with a blind spot that made the Hurricane vulnerable to attack from the rear.



ENGINE

The Rolls-Royce Merlin was a liquid-cooled, 12-cylinder inline aircraft engine developed in the early 1930s, with its first run on 15 October 1933. The versatile Merlin was one of the most successful aircraft engines of World War II, also powering the Avro Lancaster bomber, Supermarine Spitfire fighter, and improving the performance of the North American P-51 Mustang fighter. The Merlin engine delivered 1,030 horsepower, giving the Hurricane a top speed of 318 miles (512 kilometres) per hour. Performance improved throughout the war, and nearly 1,500 machines were built at Rolls-Royce factories in Glasgow, Derby and Crewe, and in Ford of Britain's Trafford Park facility near Manchester.



Above: Schoolboys admire the inner workings of the powerful Rolls-Royce Merlin engine

BROWNING
.303-CALIBRE
MACHINE GUNS

SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1937
RANGE: 460 MILES (740km)
TOP SPEED: 318mph (512km/h)
ENGINE: LIQUID-COOLED V-12 ROLLS-ROYCE MERLIN II OR III
WEAPONS: 8x BROWNING .303-CALIBRE MACHINE GUNS; 2x 250lb (113kg) OR 500lb (227kg) BOMBS

COCKPIT

The Rolls-Royce Merlin was a liquid-cooled, 12-cylinder inline aircraft engine developed in the early 1930s, with its first run on 15 October 1933. The versatile Merlin was one of the most successful aircraft engines of World War II, also powering the Avro Lancaster bomber, Supermarine Spitfire fighter, and improving the performance of the North American P-51 Mustang fighter.

The Merlin delivered 1,030 horsepower, giving the Hurricane a top speed of 318 miles (512 kilometres) per hour. Performance improved throughout the war, and nearly 1,500 were built at Rolls-Royce factories in Glasgow, Derby and Crewe, and in Ford of Britain's Trafford Park facility near Manchester.



“THE ROLLS-ROYCE MERLIN WAS A LIQUID-COOLED, 12-CYLINDER INLINE AIRCRAFT ENGINE DEVELOPED IN THE EARLY 1930S, WITH ITS FIRST RUN ON 15 OCTOBER 1933”

FUSELAGE OF DURALUMIN AND WOOD



Below: Armourers load a Hawker Hurricane's wing-mounted Browning .303-calibre machine guns



ARMAMENT

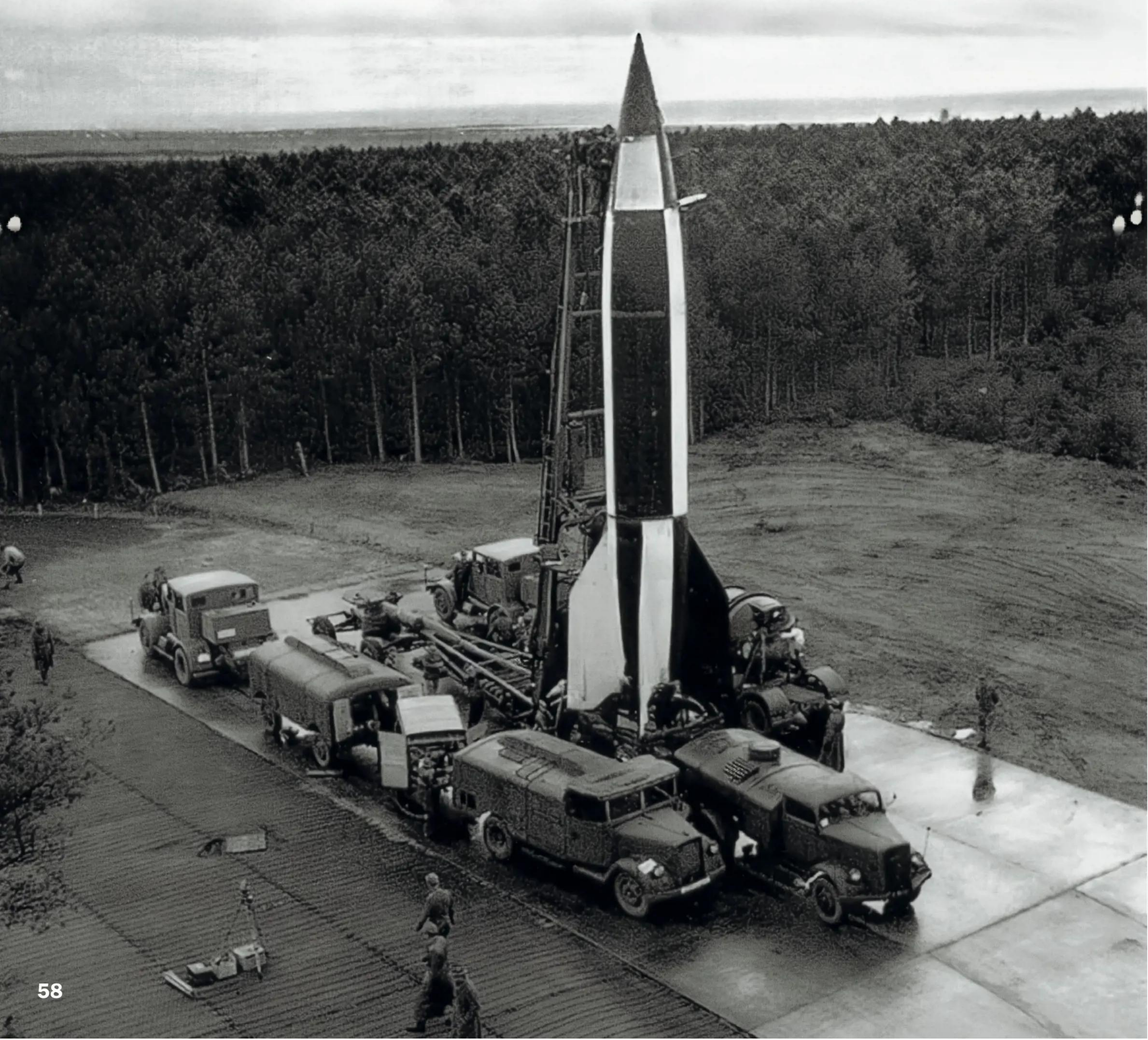
The early production Mk. I Hurricane was armed with eight wing-mounted Browning .303-calibre machine guns, while later versions mounted a variety of weapons. The IIB, for example, was upgunned with 12 .303-calibre machine guns and racks for a pair of 250-pound (113-kilogram) or 500-pound (227 kilogram) bombs. The IIC carried four powerful Hispano 20mm cannon and retained bomb capability, while the IID mounted a pair of Vickers 40mm S guns and two .303-calibre machine guns. The Hurricane IV carried two 40mm S guns, two .303-calibre machine guns and a pair of 500-pound (227-kilogram bombs). Later variants proved to be effective tank-busting aircraft.



Second World War

V-2 ROCKET

In 1944, Hitler unleashed this devastating new 'vengeance' weapon



The world's first large-scale liquid-propellant rocket was developed between 1936 and 1942 in Germany. It's regarded as a revolutionary breakthrough in rocket technology, with the use of liquid fuel increasing its thrust capabilities and making it the first artificial object to enter space.

The V-2 was the most advanced rocket of its time when it was first launched in 1944. However, the purpose of its production was deadly. The 'V' in its name stood for 'Vergeltungswaffe', meaning 'vengeance weapon' in German. As the first long-range guided ballistic missile, the Nazis used the rocket to attack their enemies during World War II. During the war, these missiles killed around 9,000 people.

Each V-2 missile was 46 feet (14 metres) long, 5 foot (1.6 metres) wide and carried 900 kilograms of explosives. Along with the greater range that was achieved by the liquid

propellant, the V-2 rocket was also equipped with a guidance system – something that provided it with much improved accuracy compared to its predecessors. The rocket's automatic guidance system included an onboard computer which was programmed with the rocket's target destination. If the line of trajectory was altered for any reason, rudders in the rocket's fins could adjust to get it back on course.

After the widespread use of the V-2 as a war weapon, the potential of the rocket's technology in future combat and space applications was realised. Soon after the war ended, the V-2, which was once responsible for taking so many lives, was the key to accelerating human exploration of space. Today liquid fuel is still the propellant of choice for space missions. The V-2 is remembered for its contribution to today's knowledge of distant worlds, but its dark origins and deadly application in warfare aren't forgotten.



ROCKET COMPONENTS

How this large liquid-propellant rocket was designed

SPECIFICATIONS

COUNTRY OF ORIGIN: NAZI GERMANY
FIRST FLIGHT: 1942
RANGE: 200 MILES (320km)
TOP SPEED: OVER 3,500mph (5,600km/h)
ENGINE: LIQUID-FUELLED ROCKET ENGINE
WITH 56,000lb (25 METRIC TONS) THRUST
WARHEAD: 1,627lb (738kg) EXPLOSIVES

HYDROGEN PEROXIDE CONTAINER

Fuel and liquid oxygen pumps were powered by a steam turbine. Concentrated hydrogen peroxide produced this steam.



The first US test of a captured V-2 rocket in 1946

ENGINE

During combustion, this area reached temperatures between 2,500 and 2,700 degrees Celsius.

ANTENNA

The antenna received and transmitted radio signals for missile tracking.

STABILISING FINS

The rocket's fins had a wingspan of 11.6 feet (3.56 metres).

THRUST VANES

Small devices called vanes were placed in the rocket's exhaust to deflect thrust.

“THE V-2 WAS THE KEY TO ACCELERATING HUMAN EXPLORATION OF SPACE”

V-2 rockets caused significant damage in London



FUEL TANK

This tank held a mixture of 75 per cent alcohol and 25 per cent water.

WARHEAD

The rocket warhead contained 1,627 pounds (738 kilograms) of explosives.

MISSILE CONTROL

A device called a gyroscope sensed the acceleration and angle of the rocket to guide it towards its target.

LIQUID OXYGEN TANKPEROXIDE CONTAINER

For the fuel to burn quickly and under pressure, it was combined with liquid oxygen.

SUCTION LINE

This line delivered the liquid propellant to the rocket's engine.

ROCKETING INTO SPACE

There are two legacies left behind by the V-2 rocket. While one is of disaster and destruction, the deadly missile's technology was later used in a key milestone of space travel. Wernher von Braun and some of his colleagues moved to the US after WWII, where they worked to develop the Saturn V. The V-2 rocket became the first to enter space during a test carried out by the Nazis in 1944. During this test, the rocket passed the boundary between Earth's atmosphere and outer space. After the war, US president Dwight D. Eisenhower moved the rocket development centre from the army to NASA to change the focus of von Braun's work. At NASA, the rocket scientist had to alter the advanced technology to produce a rocket that could stay in space rather than one designed to fall on cities. His team's experience in handling the large V-2 rocket assisted the US in the Space Race, with von Braun becoming the chief architect of the Saturn V launch vehicle. This vehicle successfully brought the first astronauts to the Moon in 1969.



Above: The Saturn V rocket was the V-2's spacefaring successor

MESSERSCHMITT

ME 262

This early jet fighter brought terrifying speed and combative dominance but was too late to turn the tide of the war for Nazi Germany

Speed kills. This is a fact of war that the Nazi regime understood well, employing it to great effect with their 'Blitzkrieg' (lightning war) tactics of WWII, puncturing holes in Allied lines with great speed and firepower. It was a mantra they incorporated into all aspects of their military and, as shown in the groundbreaking Messerschmitt Me 262 fighter jet, often generated spectacular results.

The Me 262 was the most advanced aviation design brought to fruition during World War II, and the first ever operational jet-powered fighter aircraft in the world. It featured a state-of-the-art, streamlined steel and aluminium alloy chassis, twin super-powerful Junkers Jumo 004 B-1 turbojet engines and a suite of weaponry that allowed it to fulfil a wide variety of roles. It was originally conceived to be a high-speed fighter-interceptor used to take down Allied bombers during sorties (flight missions), however under order from Adolf Hitler himself, its role was widened to also include bombing duties.

Its aerial dominance rested on its high top speed of 560 mph (900km/h), which obliterated its nearest rivals, the American P-51 Mustang and British Spitfire. Indeed, the extreme velocity that the Me 262 brought to the aerial battlefield meant that traditional dog-fighting tactics needed to be rewritten, with Allied pilots unable to track the aircraft with their electric gun turrets.

Instead, Allied pilots had to gang up and attempt to force the 262's pilot into making low-speed manoeuvres, from which it could be shot down. This formidable power came from the turbojets. They didn't provide as much thrust at lower speeds than that of propellers, meaning that Me 262s took longer to reach high speed.

However, once flying, the aircraft could easily outpace any Allied plane. Further, the turbojets granted the Me 262 a higher rate of climb than its contemporaries, which, when used tactically, allowed them to out-position the enemy and line up attack runs on lower-flying bombers. Air-to-air damage was delivered with four 30mm MK 108 cannons, as well as 24 55mm R4M rockets. The Me 262's cannons

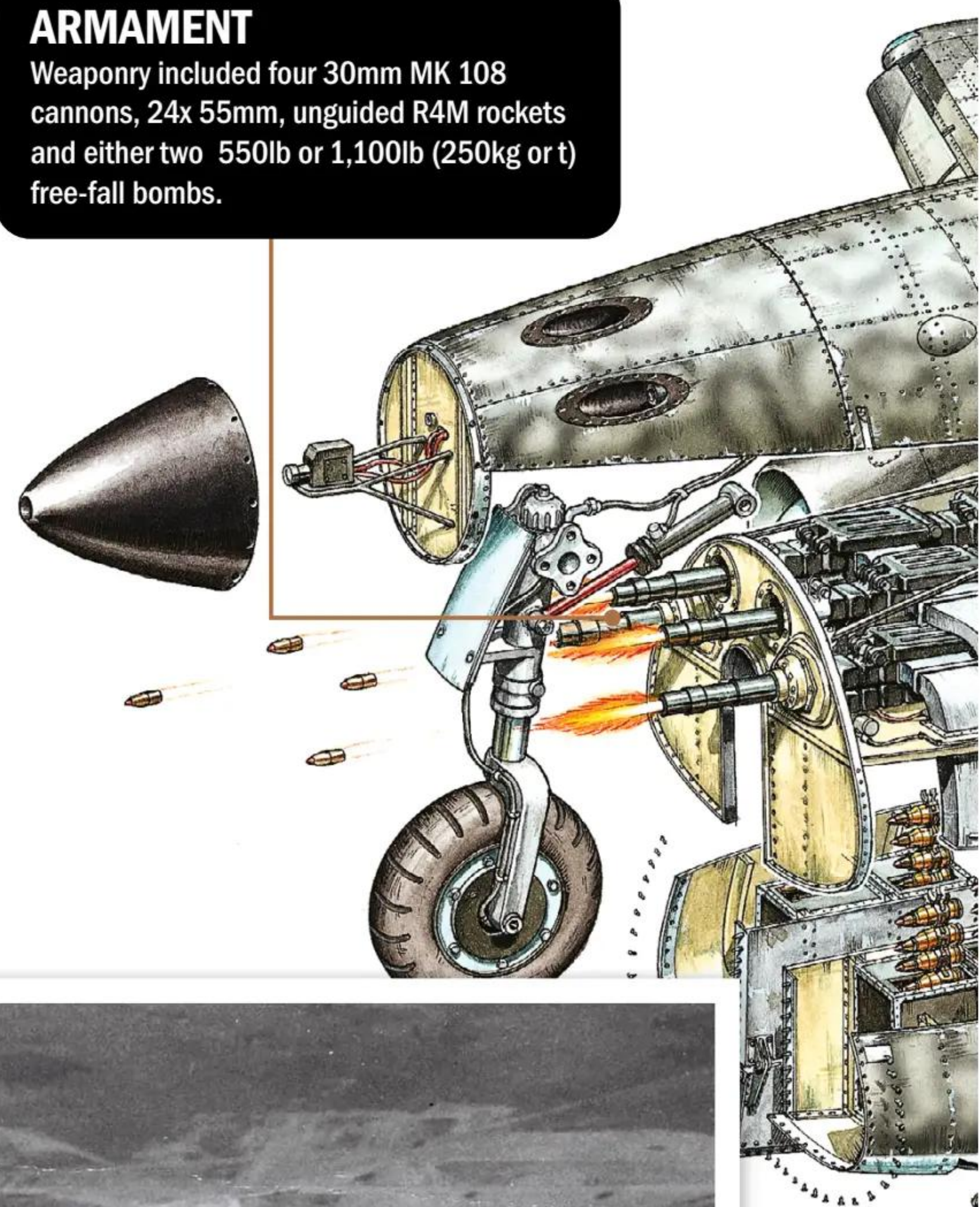
allowed for short-range firing runs, while the unguided R4M rockets allowed larger targets to be peppered with high-explosive munitions, each one capable of totally destroying any aircraft of the day.

Air-to-ground attacks were carried out through a selection of 550lb to 1,100lb (250kg or 500kg) free-fall bombs, which were stored and released from dedicated bomb bays. Through its weaponry and intense speed, the Me 262 racked up a reported five-to-one kill rate, shooting down a variety of different Allied aircraft. Unfortunately, the reign of the Me 262 was short-lived, as mass delays in bringing it to operational functionality meant that it was not introduced until the spring of 1944, just over a year before the close of the war.

Poor parts availability and dissemination of maintenance information to mechanics led to serious deficiencies in fleet fly time, with few aircraft in the air at any one time. Due to its aerial dominance, Allied forces identified the Me 262's potential threat and dedicated large quantities of bombing sorties to destroying construction factories and launch bases.

ARMAMENT

Weaponry included four 30mm MK 108 cannons, 24x 55mm, unguided R4M rockets and either two 550lb or 1,100lb (250kg or t) free-fall bombs.



The Messerschmitt Me 262 Schwalbe, as seen in this photograph, was the first variant of the jet to fall into Allied hands

INSTRUMENTATION

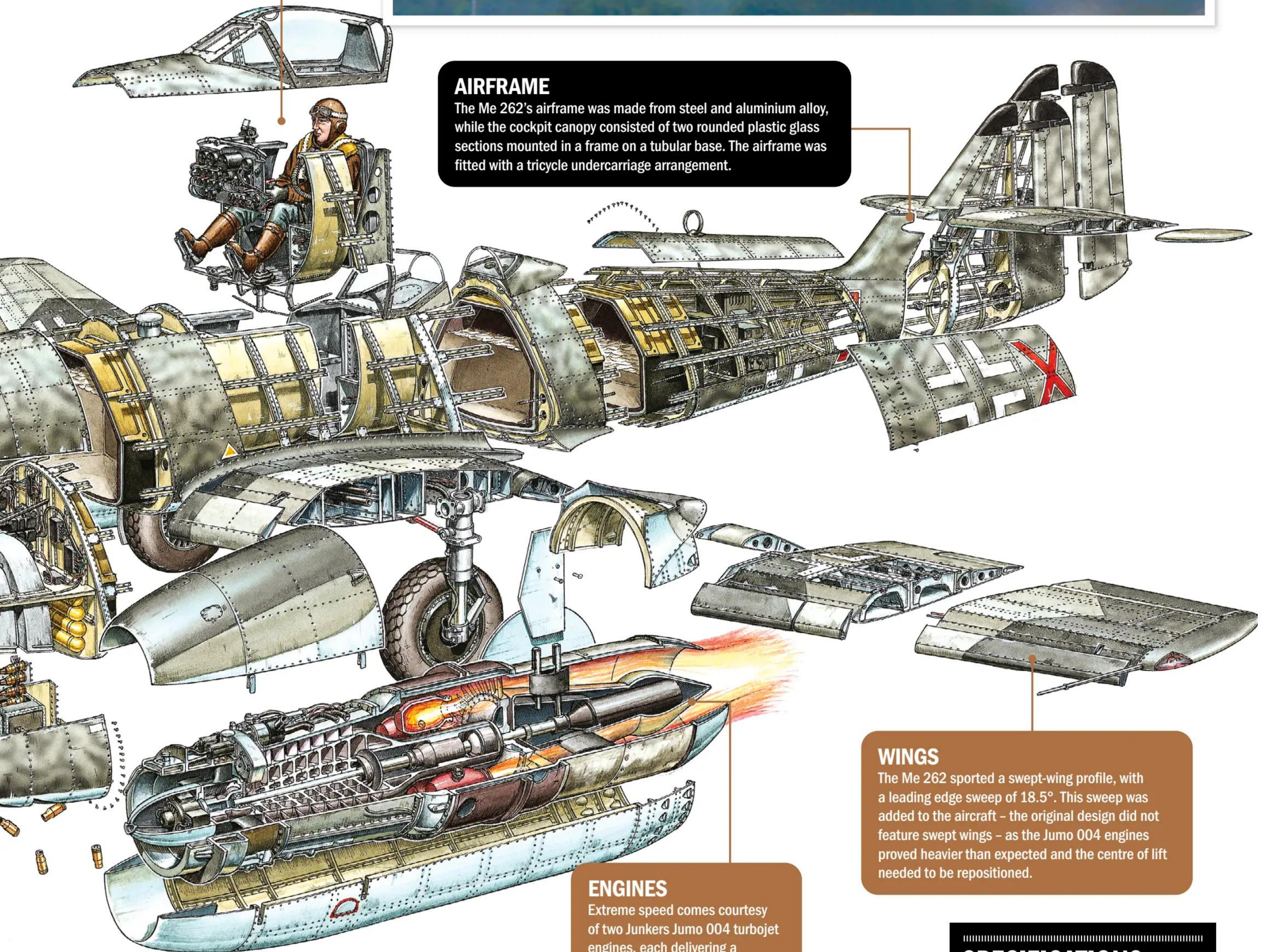
Flight instruments in the Me 262's cockpit included an artificial horizon, bank and turn indicators, airspeed indicator, altimeter, rate of climb indicator, repeater compass and a blind approach indicator.



The Me 262's engines allowed a top speed of 900km/h

AIRFRAME

The Me 262's airframe was made from steel and aluminium alloy, while the cockpit canopy consisted of two rounded plastic glass sections mounted in a frame on a tubular base. The airframe was fitted with a tricycle undercarriage arrangement.

**WINGS**

The Me 262 sported a swept-wing profile, with a leading edge sweep of 18.5°. This sweep was added to the aircraft – the original design did not feature swept wings – as the Jumo 004 engines proved heavier than expected and the centre of lift needed to be repositioned.

ENGINES

Extreme speed comes courtesy of two Junkers Jumo 004 turbojet engines, each delivering a whopping 1,980lb (900kg) of force. This gave the fighter a top speed of 560mph (900km/h), over 100mph (160km/h) more than its nearest competitor.

SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: NAZI GERMANY
COMMISSIONED: 1944
RANGE: 652 MILES (1,050km)
TOP SPEED: 559mph (900km/h)
ENGINE: 2x JUNKERS JUMO 004 B-1 TURBOJET ENGINES
WEAPONS: 4x 30mm MK 108 CANNONS, 24x 55mm R4M ROCKETS, 2x 250kg BOMBS

“THE ME 262 WAS THE MOST ADVANCED AVIATION DESIGN BROUGHT TO FRUITION DURING WORLD WAR II”

SUPERSONIC LOW ALTITUDE MISSILE

This prototype weapon would have had made a terrifying impact in the event of a third world war



TRACKING AND COMMUNICATIONS

SLAM was accurate to within around a single nautical mile, or about 1.8 kilometres. Flight computers and antennae were housed in the nose cone and were shielded from the nuclear payload and ramjet. It could reach any target on Earth inside of around two hours

RAMJET

The nose cone retracted during flight to provide the air inflow for the nuclear ramjet. This type of engine is air-breathing and cannot produce thrust unless the vehicle is moving at speed. SLAM used nuclear fission to heat the air to around 500 degrees Celsius (932 Fahrenheit) and compressed to 316 pounds per square inch.

The Supersonic Low Altitude Missile – or SLAM – was developed under the similarly innocuous-sounding code name Project Pluto and was an unmanned vehicle for a nuclear payload. In the event of the anticipated nuclear war, it could be launched to fly at supersonic speeds of up to Mach 4.2 over extreme ranges of nearly 120,000 miles (200,000km).

It could achieve these speeds at low altitude and below enemy radar, trailing a powerful sonic shockwave that could shatter windows, flatten small structures and burst eardrums.

SLAM was capable of deploying a varied payload, from a single 6,400lb (2,902kg) nuclear bomb to several 350lb (159kg) bombs on multiple targets. This made it a versatile weapon of mass destruction and certainly one to be feared if it had ever been commissioned.

But it's the ramjet engine that is SLAM's particularly horrible innovation. This device superheated air from the inflow via nuclear fission, rather than igniting chemical fuel. As a result, its exhaust wasn't a benign contrail left in the sky, but radioactive fallout that would contaminate the ground below it.

Even more devastating, the reactor core was practically unshielded, blasting any living thing along SLAM's flight path with a deadly dose of direct neutron radiation. Once its supersonic journey was complete, the SLAM would then career into its strategically chosen crash site, which would be heavily irradiated by the exposed engine core.

Thankfully, the inherent problem of safely testing the nuclear ramjet as well as its cost, among other factors, meant SLAM was ultimately shelved in 1964, without a successful flight test.

“THE REACTOR CORE WAS PRACTICALLY UNSHIELDED, BLASTING ANY LIVING THING ALONG SLAM’S FLIGHT PATH”

NUCLEAR PAYLOAD

SLAM could carry one large nuclear bomb or several smaller bombs, which could be dropped on separate targets. This was its primary weapon, although the radioactive contamination it spread could be just as devastating.

BOOSTERS

Although the nuclear ramjet would be activated at the moment of launch, the missile launch itself would be via chemical rocket boosters to a safe cruising altitude.

NEVADA TEST SITE

After the first use of nuclear weapons in 1945, the US Government founded the Atomic Energy Commission in 1946 to regulate, control and develop nuclear materials. Comprised of dozens of separate areas, nuclear tests were conducted at the site between its opening in 1951, until testing was officially ceased in 1992. Over 800 nukes were tested, mostly underground, during this time, leaving the landscape visibly scarred with craters. In 1970 the 10-kiloton Baneberry test went wrong and the radioactive cloud emitted by the blast escaped up to 10,000 feet (3,084 metres) into the atmosphere.

SPECIFICATIONS

COUNTRY OF ORIGIN: USA
FIRST FLIGHT: N/A
RANGE: 120,000 MILES (200,000km)
TOP SPEED: 3,196mph (5,145km/h)
ENGINE: TORY II-C NUCLEAR RAMJET REACTOR
WARHEAD: 6,400lb (2,902kg) NUCLEAR BOMB



F-16 FIGHTING FALCON

Arguably the world’s most successful jet fighter, the Fighting Falcon has served in nations around the world, in conflicts spanning decades

Entering service with the USAF in 1978, the F-16 quickly spread around the world. It was used by the USAF over Iraq from 1991 onwards, and with the USAF and various European forces over the Balkans, Afghanistan and Libya. The type has also seen combat over the Pakistan-India border, Israel’s borders, over Syria with the Turkish Air Force, and over the Sinai with the Egyptians, as well over Yemen with the Moroccan and Bahraini air forces. Easy to maintain, highly capable and now fully adapted for strike operations, the F-16 has proven an extremely popular and cost-effective force-multiplier for many nations around the globe.

The F-16 remains in production even after 50 years, and several Eastern European countries have either ordered or stated an intent to order them to replace their slightly younger Mikoyan MiG-29s. Ukraine is one of those countries, with the support of Britain, the Netherlands, Denmark and Belgium to train their pilots.

“THE F-16 WOULD LATER BE DEVELOPED INTO A HIGHLY CAPABLE ALL-WEATHER MULTI-ROLE AIRCRAFT”

COCKPIT

One of the F-16’s most distinctive features is the high bubble canopy. Frameless and reinforced to protect against bird strikes, the bulging sides combined with very high-set seat provide a 360° view, with a remarkable 40° down-view. The pilot’s ejector seat is also set at a 30° angle, helping them cope with high-G manoeuvres. Primary flight controls are similarly adapted, with a side-mounted control column on the right and throttles on the left, both fitted with numerous other controls which the pilot might otherwise struggle to reach while under high-G.

GAPING AIR INTAKE

A distinctive feature is the unsightly and seemingly ungainly air intake under the cockpit. It is set far enough back to reduce drag and minimise air-flow loss. A splitter plate is used to control air flow.

A Turkish Air Force F-16 demonstrates its self-defence suite



SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: USA
COMMISSIONED: 1972
RANGE: 2,002 MILES (3,221km)
TOP SPEED: 1,500mph (MACH 2)
ENGINE: GENERAL ELECTRIC F110-GE-129
 OR PRATT & WHITNEY F100-PW-229
 AFTERBURNING TURBOFAN
WEAPONS: UP TO 16,975lb (7,700kg) OF
 AIR-TO-AIR MISSILES, BOMBS OR ROCKETS
 M61A1 VULCAN ROTARY CANNON

VARIABLE-CAMBER WINGS

Flaperons along the leading and trailing edges of the wings are automatically controlled by the on-board computer, varying the camber of the wings to maximise performance.

ENGINE

The Falcon was originally fitted with the Pratt & Whitney F100-PW-200 afterburning turbofan, a development of the -100 that was built for the F-15 Eagle. Rated at 23,830lbf (106kN), the engine initially had reliability issues but subsequent developments of the -220 and -220E greatly improved it. Today, F-16s tend to have the General Electric F110-GE-12, rated at 29,388lbf (131.61kN) with afterburner, or the Pratt & Whitney F110-PW-229, rated at 29,160lbf (129.7kN) with afterburner.

FULLY MOVING STABILISERS

After some early stability issues, the F-16 was fitted with larger and fully moving horizontal stabilisers, improving performance at high angles of attack, assisting with stall recovery and aiding faster take-offs.

ARMAMENT

The F-16 has a 20mm M61A1 Vulcan six-barrelled cannon in the fuselage to the left of the cockpit, and also carries a fearsome array of other weaponry. Initially designed to carry two AIM-9 Sidewinder missiles, one on each wing tip, continuous developments have seen the number of hard-points rise to 11, of which nine can carry ordnance (the others carrying sensors and other systems) or external fuel tanks. Up to 16,975lb (7,700kg) of air-to-air or air-to-ground missiles, iron and smart bombs, or rockets can be carried to meet almost any mission requirement.

CLOSE-SET UNDERCARRIAGE

The F-16 has a close-set and surprisingly simple tricycle undercarriage. In order to keep the wing thin, it folds into the lower fuselage.



20th Century

LOCKHEED U-2

America's most covert
Cold War aircraft

While Lockheed's U-2 spy plane remains in operation to this day, it is still synonymous with the Cold War era, not least because of some high-profile successes and failures. Originally designed by Clarence 'Kelly' Johnson in 1953, the plane was intended as a response to the seeming intelligence hole the United States was experiencing as the USSR built up its arsenal of weapons. This new plane would enable the US to see what was happening behind the Iron Curtain.

The first test flight for the U-2 took place at a remote airbase in the Nevada Desert, known today as Area 51. The test was successful and the very next year, in 1956, it was put into service by both the United States Air Force and the Central Intelligence Agency. Its early missions were reconnaissance into the USSR, looking for intel into its missile and nuclear weapons programmes. For instance, it was a U-2 plane that spotted the nuclear weapons in Cuba during the 1962 missile crisis. It would also be used to detect nuclear weapons testing in the upper atmosphere.

The primary reason why the U-2 was so successful was the incredible altitudes it could reach – up to 21km. This meant that, while it could still be spotted on radar, it could not be reached by anti-aircraft guns on the ground or by enemy aircraft. That said, one of its most infamous episodes was the U-2 Incident, when the U-2 plane of Francis Gary Powers was shot down on 1 May 1960 by a newly developed Soviet surface-to-air-missile.

The versatility of the plane has meant it has long out-lived its expected lifespan, managing to compete as an intelligence-gathering tool in the age of satellites and supersonic aircraft. Even the advent of drones, expected to send the U-2 into retirement in 2015, has not ended its run and the plane continues to be used by the US military to this day.

WINGSPAN

With a tip-to-tip width of 103ft (31.4m), the U-2's wingspan is perfectly tuned to provide lift for its high-altitude missions. While this makes it incredibly well-suited to flight, it's an awkward plane for take-off and landing as its wide wingspan and light weight mean it's easily knocked off balance. Such challenges are what earned it the nickname Dragon Lady.

CABIN PRESSURE

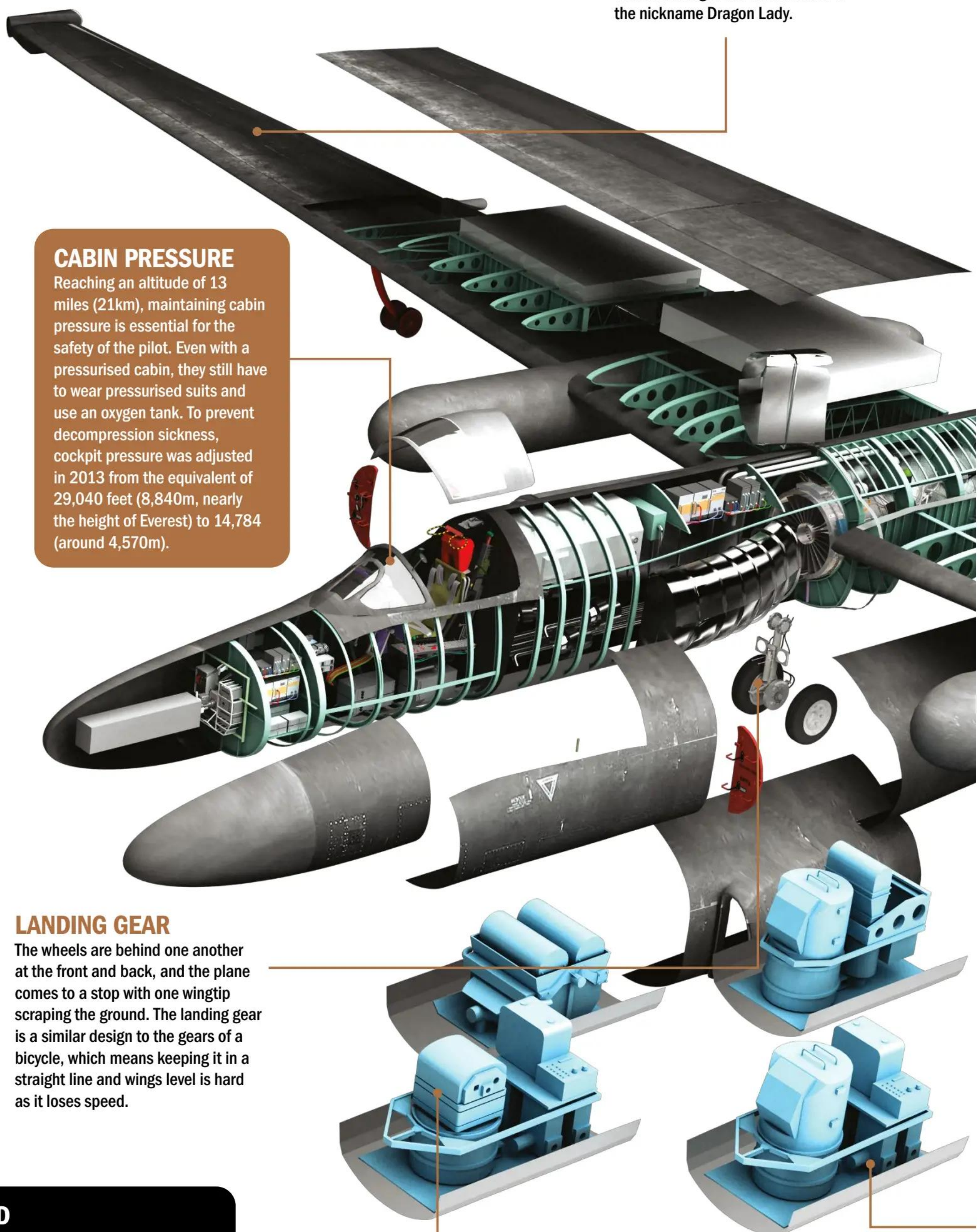
Reaching an altitude of 13 miles (21km), maintaining cabin pressure is essential for the safety of the pilot. Even with a pressurised cabin, they still have to wear pressurised suits and use an oxygen tank. To prevent decompression sickness, cockpit pressure was adjusted in 2013 from the equivalent of 29,040 feet (8,840m, nearly the height of Everest) to 14,784 (around 4,570m).

LANDING GEAR

The wheels are behind one another at the front and back, and the plane comes to a stop with one wingtip scraping the ground. The landing gear is a similar design to the gears of a bicycle, which means keeping it in a straight line and wings level is hard as it loses speed.

PAYLOAD

Even at such high altitude, the aircraft can carry 5,000lb (2,270kg) of sensors and other mission-specific equipment. Different types of sensors and apparatus can be plugged into the plane depending on what's required for its mission.



SENSORS AND DISPLAY

Electro-optical/infrared sensors feed data into the cockpit, presenting information clearly to the pilot. However, while the pilot gets plenty of information about the operation of the plane, the devices and sensors being used are either operated in a preprogrammed automated fashion or remotely from a base on the ground.

ALTITUDE CLIMB

The U-2 is able to climb to 50,000 feet (15,240m) in about 20 minutes, and 65,000 feet (19,812m) within an hour of take-off. Remaining at this altitude is incredibly difficult as it requires a fine balance of being fast enough not to stall the engines while not being so fast that the plane is torn apart.



Francis Gary Powers was shot down in 1960 while piloting a U-2

SAFETY CAR

Landing a U-2 is very tricky and requires the help of another pilot giving radio instruction from a safety car. The primary difficulty is that when landing the view from the cockpit is very poor and its wide wingspan makes it vulnerable to instability. To counter this the pilot is given feedback from the ground as the plane approaches the runway.



NASA USE

The U-2 is used for more than just spying and gathering military intel – it's also used by NASA to collect data concerning the atmosphere, the Earth and celestial phenomena. Its high-altitude capability and ability to swap out different tech makes it an ideal flying science lab.

SKUNK WORKS

The U-2 was designed and built by the Skunk Works team at Lockheed, an engineering group that made its name building the US Air Force's first jet in 1943 in just 143 days.

MiG-15

The Soviet Union's classic 2nd generation jet fighter, code-named 'Fagot'

The MiG-15 (NATO codename 'Fagot') was the Soviet Union's first successful second generation jet fighter – one that truly took account of the aerodynamics of jet propulsion. It would serve in dozens of militaries around the world, and become the most prolific jet fighter ever built with over 17,000 made by the Russians or under licence elsewhere.

The design of the MiG-15 was based on German research into jet aerodynamics. The swept back wing improved high-speed flight characteristics, although it also led to air flow being deflected outwards, decreasing lift. This was solved by adding two full-chord boundary-layer fences on each wing. The air intake, in the nose, split so the air ran either side of the low-set cockpit before entering the engine. The engine itself filled the rear fuselage, where any hit could cause serious damage.

1930S TECHNOLOGY

The MiG-15's gunsight was a copy of the RAF's Mk. 2D (.303) gyroscopic gunsight, copied from Hawker Hurricanes given to Russia in 1941.

COCKPIT

The MiG-15's cockpit sat low in the fuselage to reduce drag, leaving the pilot with a very poor field of view below him in front, and almost no field of view behind. These problems were made worse by the lack of headroom – the canopy gave very little space for the pilot to move their head. The ergonomics of the layout were also poor, with some key switches on the right hand side, so the pilot had to let go of the control column to select them.



ENGINE

The Soviets struggled with effective jet engine designs after the Second World War, with even captured German designs and designers proving inadequate. Miraculously, they managed to buy some Rolls Royce Nenes from Britain, and put them into production as the Klimov RD-45, rated at 5,005lb (2,270kg) thrust. This enabled the MiG-15 to become reality, and an improved version of the Nene/RD-45, the Klimov VK-1, soon followed afterwards. These engines gave the MiG-15 the high rate of acceleration and superb rate of climb that made it such an effective interceptor.

SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: SOVIET UNION
COMMISSIONED: 1947
RANGE: 826 MILES (1,330km)
TOP SPEED: 668mph (1,076 km/h)
ENGINE: KLIMOV VK-1 CENTRIFUGAL-FLOW TURBOJET
WEAPONS: 1x N-37 37mm CANNON;
 2x NS-23 23mm CANNONS

HIGH AND BACK

The tail plane was based on German designs, intending to increase both lift and the turn rate at high speeds.

SLIDING FUSELAGE

The whole rear fuselage and tail could be slid back to access the engine for maintenance.

ARMAMENT

Designed as a high-altitude interceptor, the MiG-15's intended targets were Western nuclear bombers. Meant to bring down big, lumbering targets, its guns were large calibre and slow-firing with low muzzle-velocities. Equipped with one N-37 37mm cannon with 40 rounds and two NS-23 (later NR-23) 23mm cannons with 80 rounds each, this left them unsuited to the type of fast-moving dogfights they met over Korea. Aiming was made harder as the cannon types had differing ballistic characteristics, so one cannon type might hit the target while the other went high or low.

BOMBS OR FUEL

The MiG-15 could be fitted with drop tanks for extended range (jettisoned in combat), two 220lb (100kg) bombs, or unguided rockets.

REDIRECTING AIRFLOW

The chords stopped air being pushed away from the aircraft, helping generate lift.

AVRO VULCAN

This iconic Cold War warrior was built for nuclear Armageddon but is best remembered for the Black Buck raids during the Falklands War

The Vulcan was designed as a long-range medium bomber to deliver nuclear payloads on targets in the Soviet Union. The initial design called for a very high-altitude approach, going over enemy air defences.

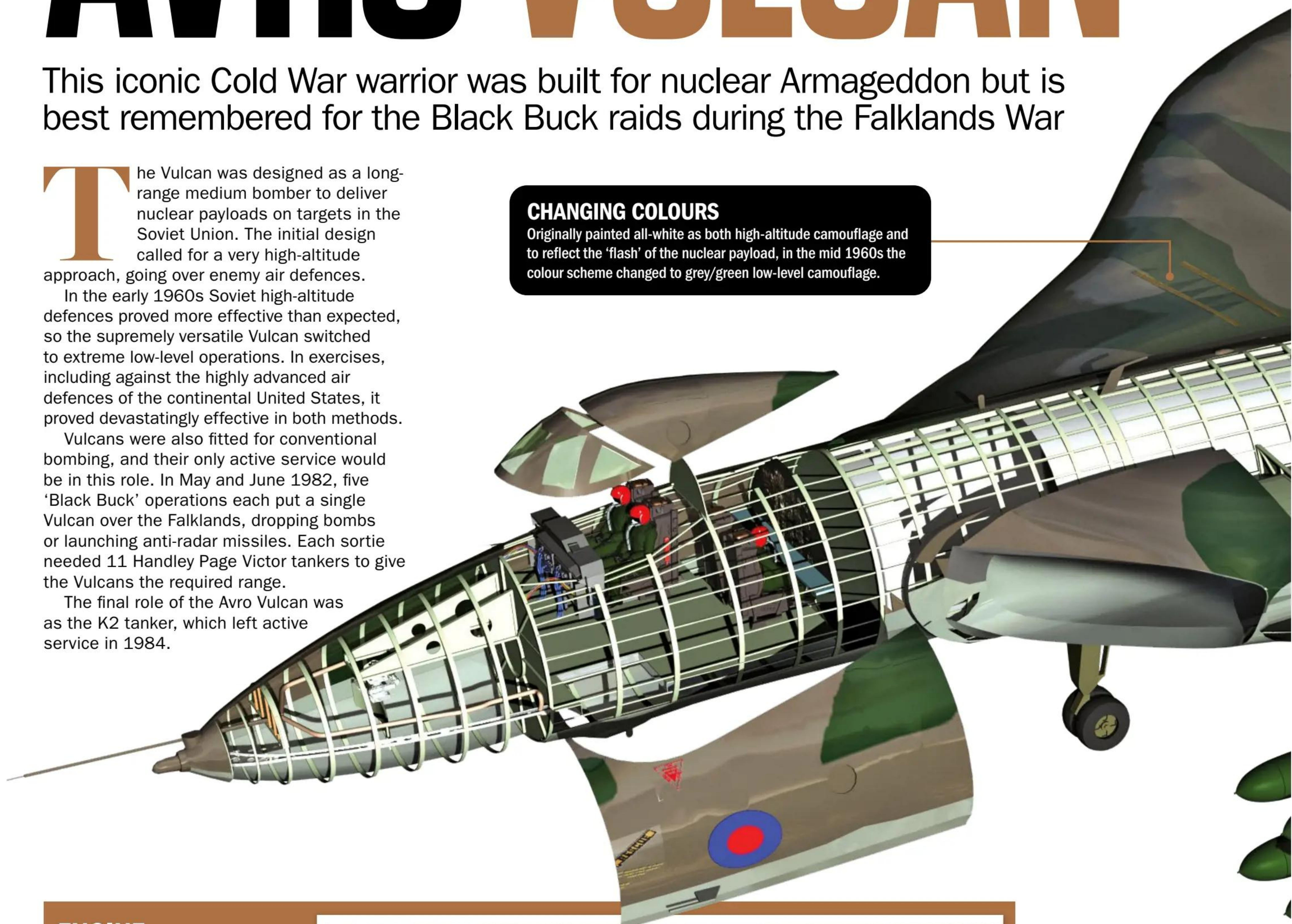
In the early 1960s Soviet high-altitude defences proved more effective than expected, so the supremely versatile Vulcan switched to extreme low-level operations. In exercises, including against the highly advanced air defences of the continental United States, it proved devastatingly effective in both methods.

Vulcans were also fitted for conventional bombing, and their only active service would be in this role. In May and June 1982, five 'Black Buck' operations each put a single Vulcan over the Falklands, dropping bombs or launching anti-radar missiles. Each sortie needed 11 Handley Page Victor tankers to give the Vulcans the required range.

The final role of the Avro Vulcan was as the K2 tanker, which left active service in 1984.

CHANGING COLOURS

Originally painted all-white as both high-altitude camouflage and to reflect the 'flash' of the nuclear payload, in the mid 1960s the colour scheme changed to grey/green low-level camouflage.



ENGINE

A number of different engines were tried until the Bristol Siddeley Olympus, first designed for Bristol's own competitor to the Vulcan, was fixed upon. The world's first two-spool axial-flow turbojet, it was initially designed in 1946 and saw several updates to provide greatly improved thrust during the 1950s. The positioning of the air intakes generated the once-heard-never-forgotten 'howl' emitted by the Vulcan at air shows. Four of these huge engines (each Olympus 301 weighed 4,300lb or 1,950kg) powered the Vulcan.



COCKPIT

The five-man crew of the Vulcan all sat in a single, crowded, pressurised cabin. Two pilots sat side by side behind fighter-style joysticks, looking forward through a very limited canopy, intended to protect the crew from the blinding flash of the nuclear payload. Behind, facing the rear, were a navigator (radar), navigator (plotter) and air electronics officer (AEO), each with imposing banks of instruments. Cutting-edge in the 1950s, much of the navigational and electronic warfare avionics would be badly dated by the 1980s. Only the pilots had ejector seats.

THE HEART OF THE MACHINE

The entire design of the Vulcan rotated around the massive bomb bay. The whole structure was developed to maximise that space.

“FIVE ‘BLACK BUCK’ OPERATIONS EACH PUT A SINGLE VULCAN OVER THE FALKLANDS”

ARMAMENT

The Vulcan was designed to carry the massive Blue Danube nuclear bomb, soon replaced by the Violet Club and Yellow Sun bombs. In 1963 these were replaced by Yellow Sun Mk. 2s for Vulcan B.1s and the Blue Steel nuclear missile for Vulcan B.2s. Vulcans could also carry 1,000-pound (21 454-kilogram) conventional bombs, which became standard after the Royal Navy took on the strategic nuclear deterrent in 1969. The tactical WE177 nuclear bomb could also be carried. In 1982, Shrike anti-radar missiles were fitted for ‘Black Buck’ operations.

UP AND AWAY

Vulcans had the power to get as high and far from their bases as possible within minutes of being scrambled, as enemy bombers or missiles would already be in-bound.

STRENGTH AND ENDURANCE

As well as providing the Vulcan’s legendary structural strength, the wing design allowed massive internal fuel tanks. Backed by air-to-air refuelling, these gave the Vulcan a global reach.

SPECIFICATIONS

CREW: 5
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1956 (B.2)
RANGE: 4,600 MILES (7,400km)
TOP SPEED: 644mph (1,038km/h)
ENGINE: 4x BRISTOL SIDDELEY OLYMPUS 201 OR 301
PAYLOAD: BLUE STEEL NUCLEAR MISSILE; 21x 1,000lb (454kg) BOMBS

20th Century

SIKORSKY MH-60 BLACK HAWK

Designed for special operations in hostile environments, this was a new kind of war machine, built for a new kind of battlefield

SPECIFICATIONS

CREW: 2
COUNTRY OF ORIGIN: USA
COMMISSIONED: 1978
RANGE: 1,367 MILES (2,200km)
TOP SPEED: 199mph (320km/h)
ENGINE: TWIN GENERAL ELECTRIC T700-GE-701C 1,940 SHAFT HORSEPOWER
WEAPONS: 2x MOUNTED M134 MINIGUNS; HELLFIRE MISSILES, ROCKET PODS, GAU-19 GATLING GUNS; DOOR-MOUNTED MACHINE-GUNS

From its introduction in the late 1970s, Black Hawks have been deployed by the US Army in the invasion of Grenada in 1983, the invasion of Panama in 1989 and during the First Gulf War in 1990-91. The MH-60 is most often associated with the Battle of Mogadishu. On 3 October 1993, two Black Hawks came under fire, crash-landing into the maze of streets and alleyways below. The battle, and the subsequent 2001 Oscar-winning film *Black Hawk Down*, gained the helicopter worldwide recognition. By 2009, the H-60 series had logged one million flight hours with the US Army.

In 2011, modified Black Hawks were used by SEAL teams during Operation Neptune Spear, the mission to kill Osama Bin Laden. During this operation one of the vehicles crash-landed and was subsequently destroyed to protect its secret modifications. Over 4,000 Black Hawks of all variants have been produced and to date continue to serve in the US and 30 other countries in a range of combat and domestic roles.

DESIGN

Modifications to the aircraft for special operations include a forward-facing infra-red (FLIR) video camera pod. This captures the surrounding environment and relays it to the pilot, enabling safe flight in total darkness. The fuel tank, landing gear and body frame are all reinforced, greatly increasing survivability. Even the pilots' seats are designed to absorb and nullify any critical impact. Many iterations, such as the MH-60G Pave Hawk, also feature an in-flight refuelling probe, to greatly extend the aircraft's operational flight time.

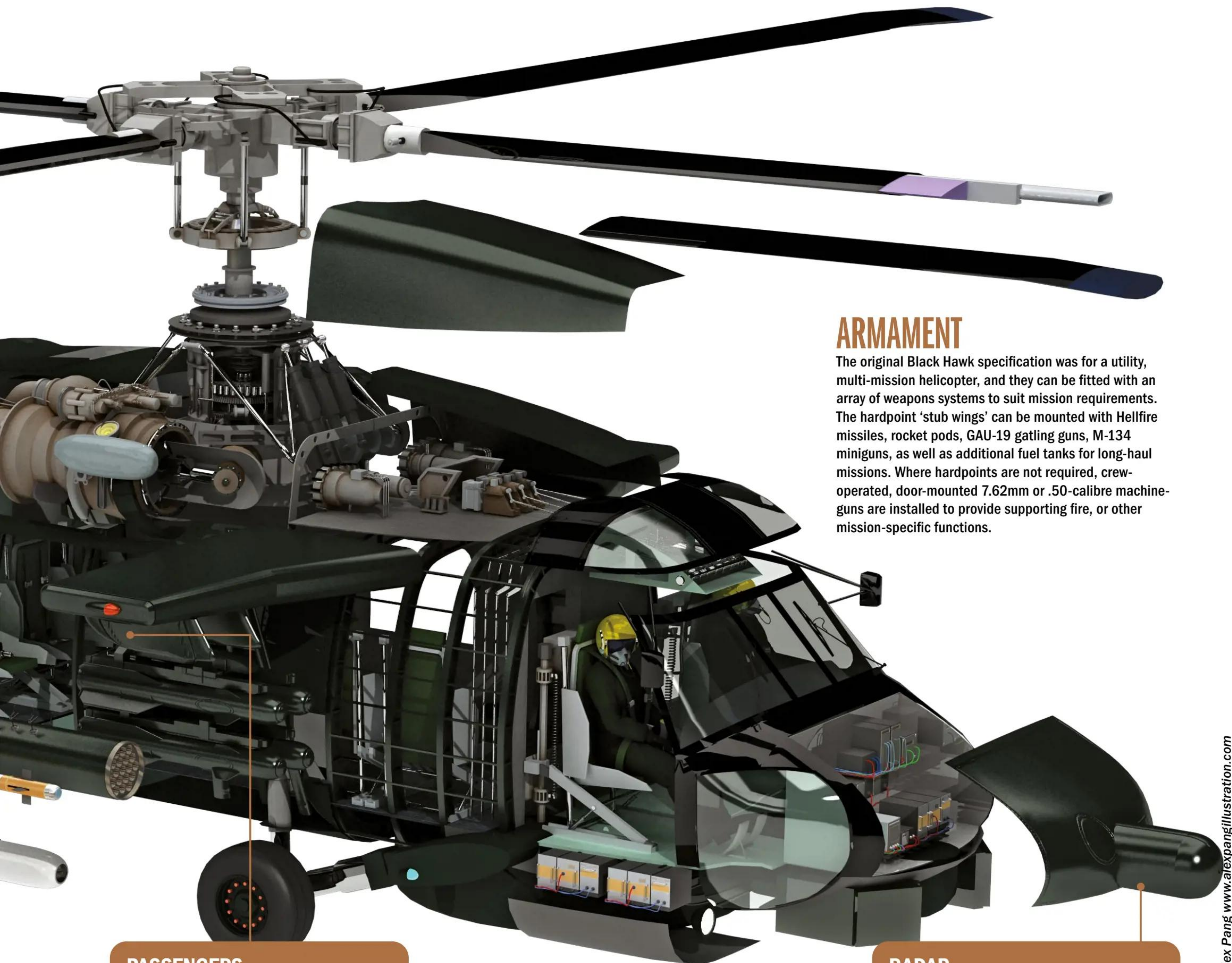
ENGINE

The General Electric T700-GE-701C turboshaft engine also powers the H-60 Seahawk for the US Navy, as well as the AH-64 Apache and a range of civilian aircraft. Later iterations of the H-60 series upgraded to T700-GE-701D engine, providing a combined 4,000 shaft horsepower, and the capacity to haul up to 22,000lbs (9,979kg) of mission weight. The reliability and high performance of these engines were ideal for the requirements and challenges of special operations as well as MEDEVAC roles.



CABIN AND COCKPIT

The pilot and co-pilot share a reinforced compartment, from where they operate and monitor integrated flight and weapons systems, including the FLIR video camera pod for use during low-visibility conditions or night flying. The UH-60M also features an integrated vehicle health management system, which gathers and displays data on status and performance. The cabin to the rear of the cockpit is capable of carrying up to 11 personnel, for the purposes of troop infiltration and exfiltration via sliding cargo doors. There is also space for stretchers in order to conduct MEDEVAC missions.



ARMAMENT

The original Black Hawk specification was for a utility, multi-mission helicopter, and they can be fitted with an array of weapons systems to suit mission requirements. The hardpoint 'stub wings' can be mounted with Hellfire missiles, rocket pods, GAU-19 gatling guns, M-134 miniguns, as well as additional fuel tanks for long-haul missions. Where hardpoints are not required, crew-operated, door-mounted 7.62mm or .50-calibre machine-guns are installed to provide supporting fire, or other mission-specific functions.

PASSENGERS

Up to 11 personnel can be transported in the rear of the aircraft, which has an operational range of over 1,367 miles (2,200km).

RADAR

As well as GPS capability, the MH-60 is fitted with multi-mode radar capable of tracking the terrain below, even in poor weather conditions.

TOMAHAWK

MISSILE

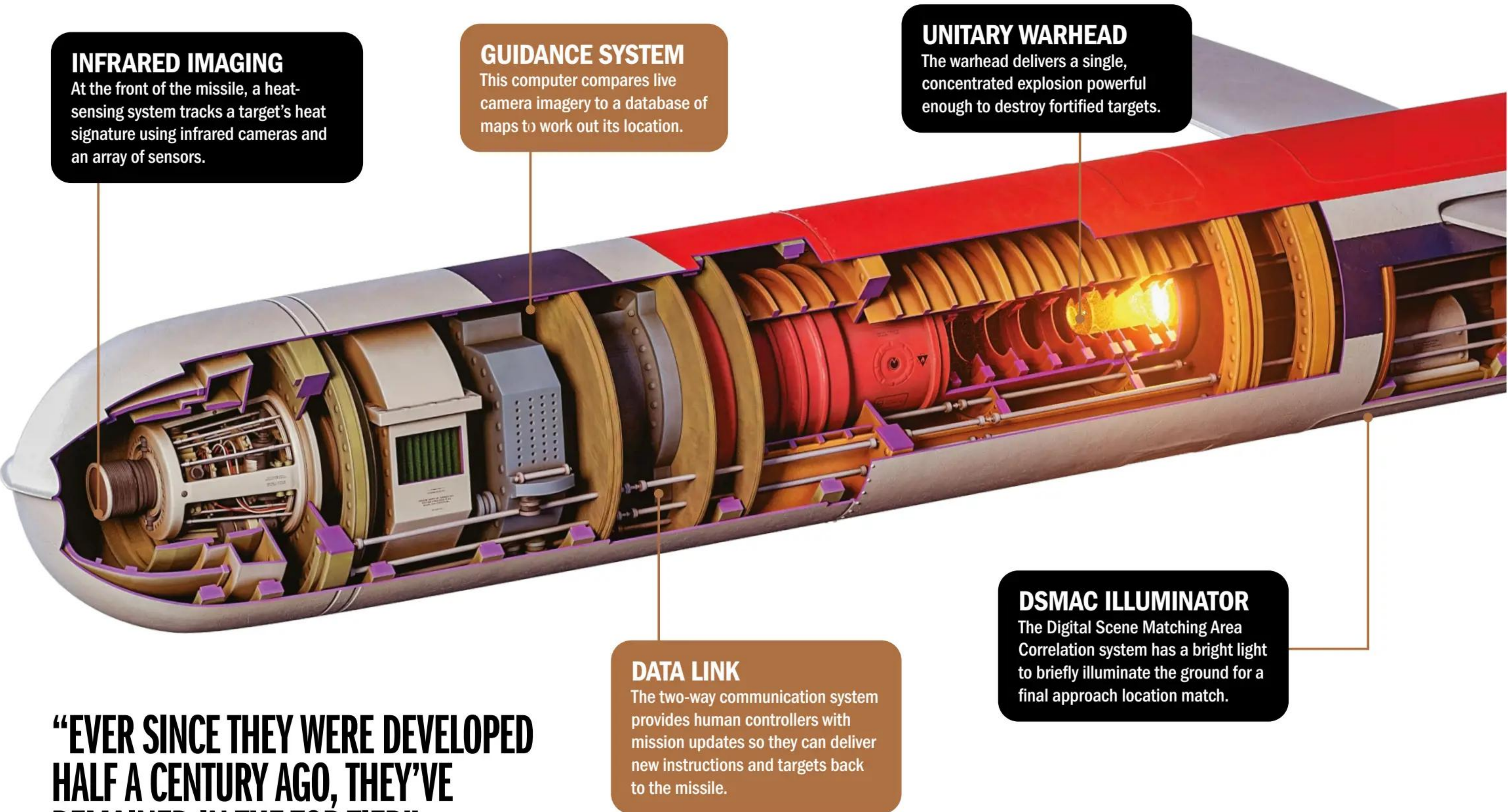
This versatile and advanced missile has served militaries all over the world for decades

Missiles are rocket-propelled weapons that often use a guidance system to direct them to their target with incredible accuracy and deadly speed. They can be launched from the ground, sea vessels or from aircraft mid-flight. Wherever the target is, these weapons can be preprogrammed or steered mid-flight to take it out. Tomahawk missiles are some of the most iconic in military history. Ever since they were

developed half a century ago, they've remained in the top tier, with regular updates keeping them effective on an ever-advancing battlefield. These missiles are able to soar through the air at low altitudes, making a precision strike from many hundreds of miles away. By closely following the terrain, Tomahawk missiles remain mostly undetectable from vehicle-mounted enemy radar. Tomahawks have been used by the US and UK in many battles in the Gulf War, Afghanistan, Iraq and Syria.

SPECIFICATIONS

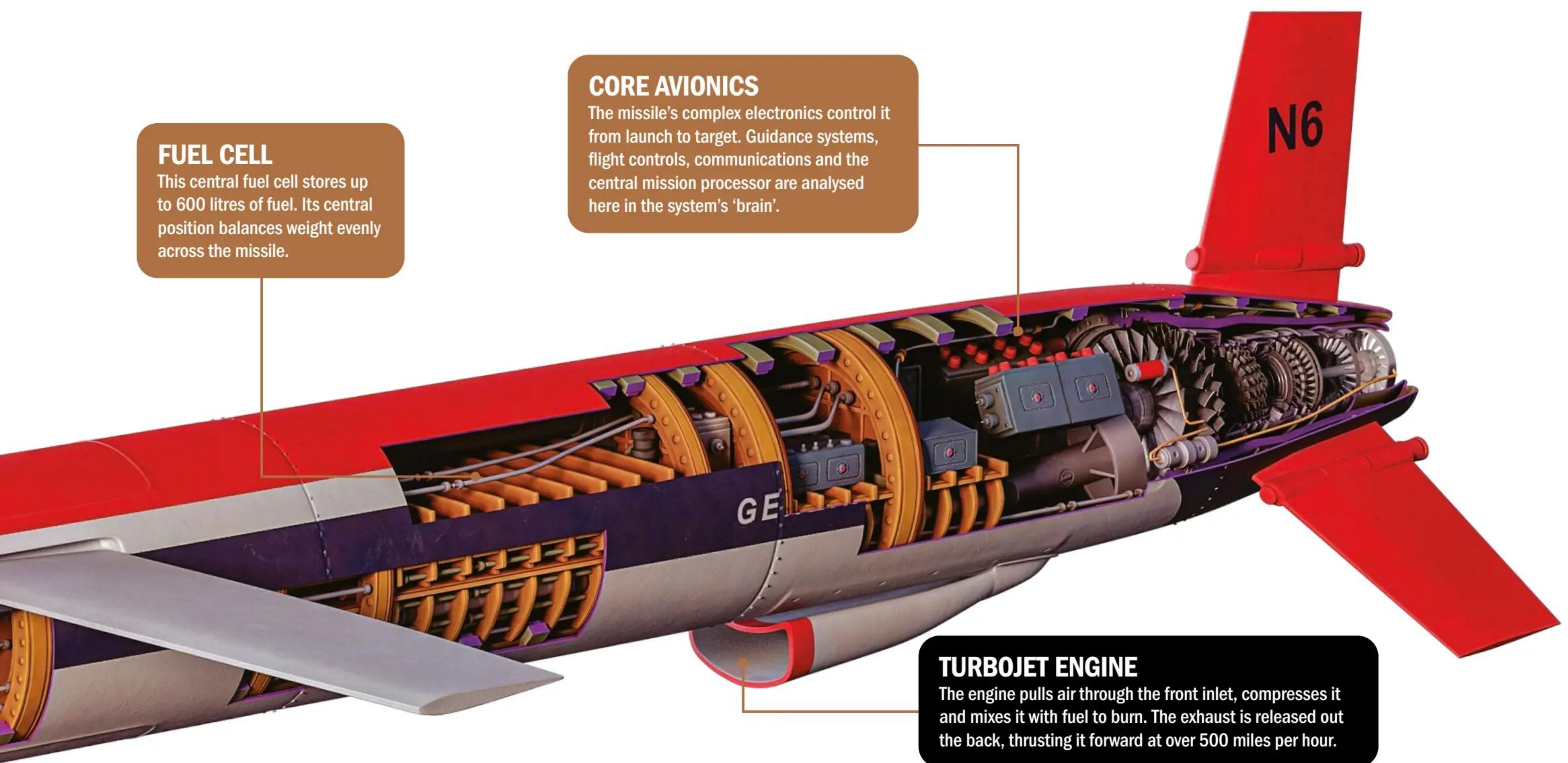
COUNTRY OF ORIGIN: USA
FIRST FLIGHT: 1976
RANGE: 1,500 MILES (2,414km)
TOP SPEED: 550mph (885km/h)
ENGINE: WILLIAMS INTERNATIONAL
415-400 TURBOFAN ENGINE
WARHEAD: 1,000lb (450kg)



“EVER SINCE THEY WERE DEVELOPED HALF A CENTURY AGO, THEY’VE REMAINED IN THE TOP TIER”



An F-14 fighter plane follows a Block IV Tomahawk missile during a controlled test



FUEL CELL

This central fuel cell stores up to 600 litres of fuel. Its central position balances weight evenly across the missile.

CORE AVIONICS

The missile's complex electronics control it from launch to target. Guidance systems, flight controls, communications and the central mission processor are analysed here in the system's 'brain'.

TURBOJET ENGINE

The engine pulls air through the front inlet, compresses it and mixes it with fuel to burn. The exhaust is released out the back, thrusting it forward at over 500 miles per hour.

ALTERNATIVE STRIKE SYSTEMS



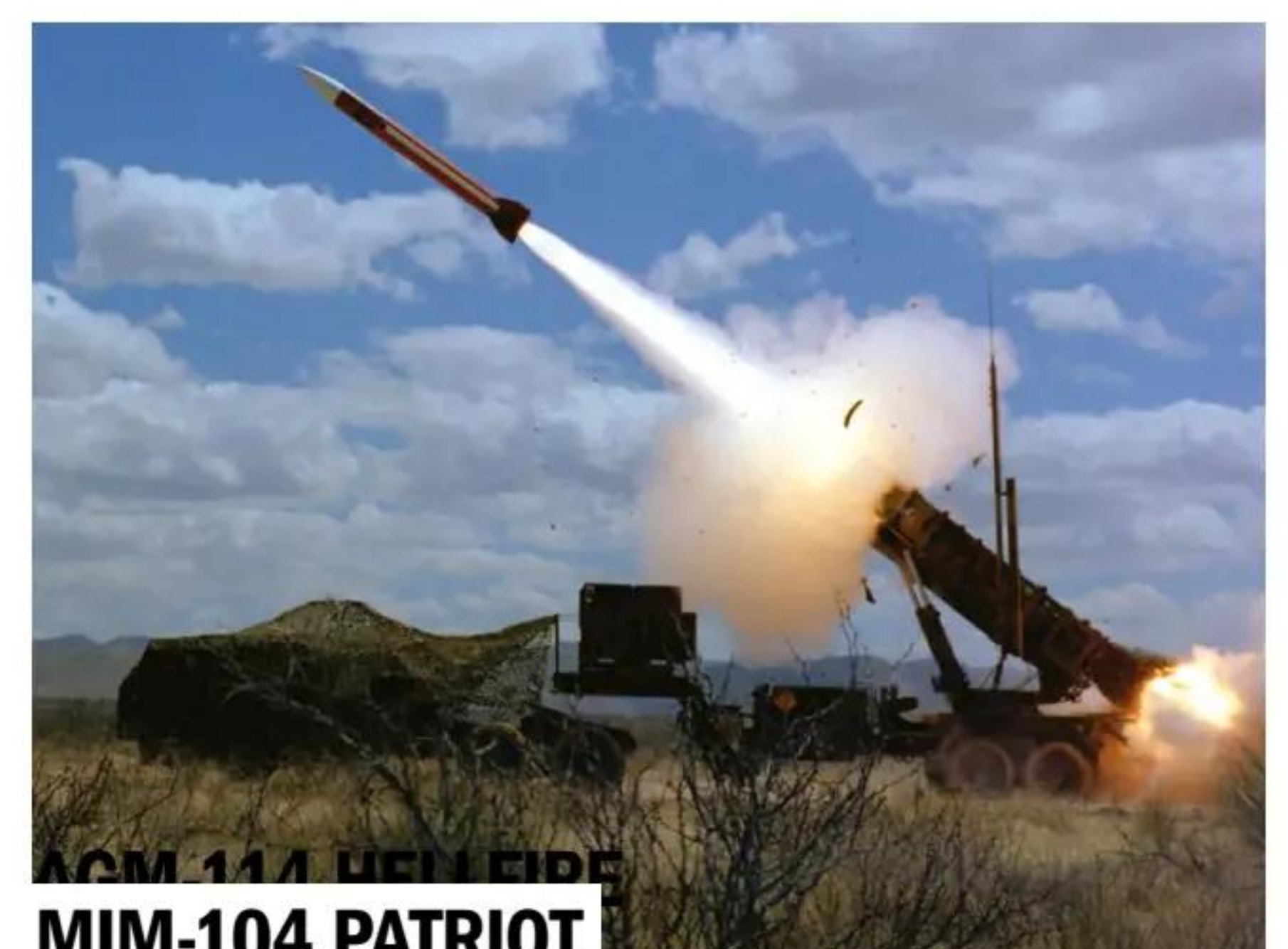
AGM-114 HELLFIRE

This air-to-surface missile, developed by the US Army in the 1980s, is still in use, launched from helicopters to target armoured vehicles on the ground.



TRIDENT II D5

The Trident II D5 is a three-stage submarine-launched missile used by both US and UK militaries.



MIM-104 PATRIOT

This long-range surface-to-air defence system was developed and is operated by the US military.

A-10 WARTHOG

Slow but steady, this Cold War close-air-support aircraft is a favourite of friendly ground forces and recognised by the buzz of its enormous cannon

After its first introduction in the late 1970s, the A-10 did not instantly gain the affection and respect it would later enjoy – its cumbersome low speed earned it the disparaging nickname ‘Warthog’ among fast jet pilots. Nonetheless, the aircraft’s ability to fly at low altitude and provide accurate ground support was deemed essential for the US military, whose experience in Vietnam had exposed major gaps in USAF’s close-air-support capacity.

Though it was too late to impact the Vietnam War, the A-10 nonetheless soon began earning a reputation for its dependability and resilience. After the end of the Cold War, A-10s participated in the first Gulf War and later during the Kosovo conflict. Though over 20 years old by the 21st century, Warthogs also took part in the 2003 Invasion of Iraq. Their strafing runs and the characteristic buzz of the 30mm cannon have gained huge popularity among infantry on operations against ISIS in Iraq and Syria, as well as in Afghanistan and elsewhere.

COCKPIT

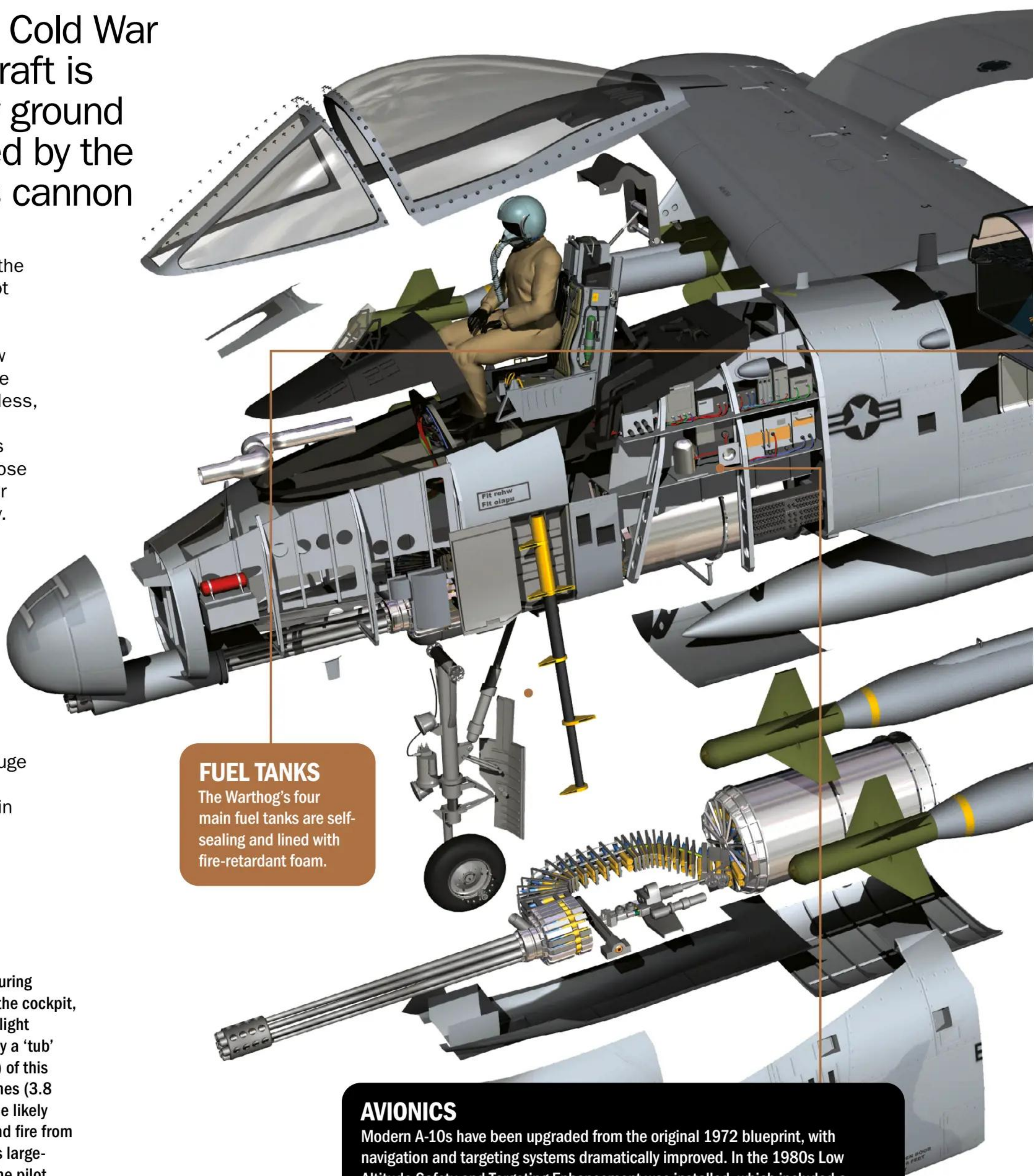
The A-10 was designed to sustain heavy damage during combat, and is particularly well-armoured around the cockpit, to increase its survivability. Sensitive parts of the flight control system, along with the pilot, are shielded by a ‘tub’ of titanium armour: 1,200 pounds (544 kilograms) of this super-hard metal is layered in plates up to 1.5 inches (3.8 centimetres) thick around the cockpit, based on the likely trajectories of incoming projectiles. It can withstand fire from similar cannons to its own main weapon, as well as large-calibre rounds. A nylon spall shield also protects the pilot from shrapnel and round fragmentation, while the transparent canopy (which can’t afford the same level of protection) can still resist ballistics from small arms.

FUEL TANKS

The Warthog’s four main fuel tanks are self-sealing and lined with fire-retardant foam.

AVIONICS

Modern A-10s have been upgraded from the original 1972 blueprint, with navigation and targeting systems dramatically improved. In the 1980s Low Altitude Safety and Targeting Enhancement was installed, which included a computerised weapons operation and a low-altitude collision warning system. A-10s were fitted with Night Vision Imaging Systems in the 1990s, enabling pilots to operate in low-visibility conditions, while after the turn of the century they received Precision Engagement upgrades, which modernised flight controls, navigation and the fire control system – these updated Warthogs are now designated A-10C.



SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: USA
COMMISSIONED: 1976
RANGE: 800 miles (1,287km)
TOP SPEED: 420mph (MACH 0.56)
ENGINE: 2× GENERAL ELECTRIC TF34-GE-100A TURBOFANS
WEAPONS: GAU-8 AVENGER 30mm

POWERPLANT

Two TF34-GE-100, non-afterburning, twin turbofans provide 9,065lb (4,111kg) of thrust each. The engines are mounted above the airframe to reduce heat signature (for evading heat-seeking missiles), as well as to enable the pilot to fly the aircraft with one engine out of action.

WINGS

As part of a service life extension programme, 242 new A-10 wing sets have been produced to extend the Warthog's operation until 2040.

ARMAMENT

The A-10 can carry nearly half its weight again in armaments and their associated systems, with an external load of up to 16,005 pounds (7,260 kilograms). It's equipped with 11 pylons along which laser weapon guidance and support systems can be attached, plus ordnance. It's capable of carrying a range of cluster and 500-pound (227-kilogram) general-purpose bombs, Hydra rockets, plus up to ten Maverick air-to-ground missiles weighing 670 pounds (304 kilograms) apiece. The latter can destroy a tank in a single hit – however, at a cost of up to £105,000 (\$160,000) a pop, a cavalier attitude with the Mavericks is not tolerated. The Warthog's main weapon is the Avenger 30-millimetre cannon mounted under the nose of the A-10, with a top fire rate of 4,200 rounds a minute and an effective range of over 4 miles (6.5 kilometres). The cannon can easily disable a main battle tank in the hands of a competent pilot.

AH-64D APACHE

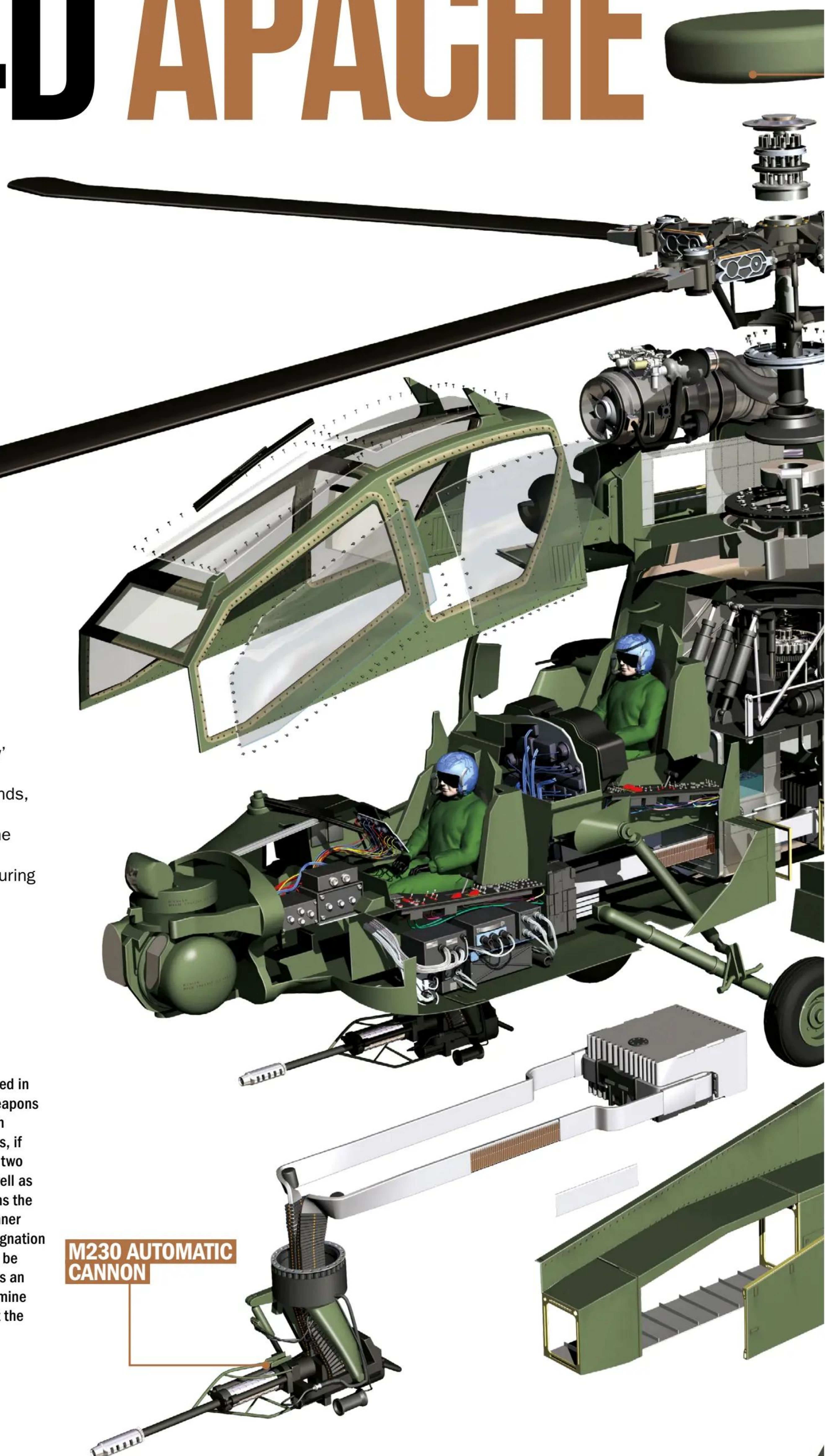
First emerging at the tail end of the 20th century, the Apache AH-64D is a multi-mission attack helicopter, designed to combat the changing face of warfare

The original Apache iteration, the AH-64A was first deployed during the US invasion of Grenada, in 1989, and soon afterwards served during the 1991 Gulf War. During Operation Desert Storm, Apache AH-64A's were sent to destroy Iraqi radar systems, enabling fast jets to then penetrate the enemy airspace and bomb high-priority targets. The modernised AH-64D 'Longbow' variant was delivered to the US Army in 1997 and was soon exported internationally, including to the Netherlands, Israel, Egypt, Singapore and Saudi Arabia. The British Army acquired a licence to produce its own variant of the Apache, the AH Mk1, to suit its own requirements. In Afghanistan it continues to serve in fire support roles during counterinsurgency operations.

COCKPIT

The Apache is designed with a split cockpit, with the pilot positioned in an elevated position behind the co-pilot, who also operates the weapons systems. The pilot's position affords greater visibility, however both sections of the cockpit can operate the flight and weapons systems, if required. The flight systems and sensors are displayed digitally on two screens. The pilot also has a Helmet Mounted Display (HMD), as well as the imagery from the Pilot Night Vision System (PNVS) which means the aircraft can be flown at night and in all weathers. The Co-Pilot Gunner (CPG) has controls for the Modernised Target Acquisition and Designation Sight (MTADS). This displays a video image in the cockpit that can be used in the day to find targets and aim the weapons, but it also has an infrared mode. The MTADS has a laser which can be used to determine the distance to a target, but it is also a coded laser that can direct the Apache's hellfire missiles on to a target.

M230 AUTOMATIC CANNON



FIRE CONTROL RADOME**FUSELAGE**

Designed for speed, manoeuvrability and stealth, the fuselage is distinctively styled and uses camouflage colours to match its operating environment.

ARMAMENT

The M230 automatic cannon fitted to the front underside of the Apache fires 30mm High-Explosive Dual-Purpose (HEDP) shells, and carries 1,500 spare rounds on board. The M230 is capable of firing a devastating 625 rounds per minute, meaning short bursts are often used to maintain accuracy and reserve ammunition. In addition several different air-to-air and air-to-surface weapons systems are available to be fitted, to suit various mission requirements. These can include Hellfire missiles, CRV7 70mm rockets and Sidewinder missiles.

COMPOSITE ROTOR BLADES

The AH-64D Longbow is fitted with a composite four-blade main rotor, allowing for increased payload, climb rate and cruise speed over earlier variants.

ENGINE

Twin turboshaft T700-GE-701C engines provide a combined total of 2,530kW. These bring a tremendous amount of power, giving the Apache a cruise speed of around 161mph (260km/h) and a top speed of 173mph (279km/h). Further upgrades to the engines and gear transmission were brought in with the AH-64E iteration of the helicopter in 2011. The British-licensed AH MK1 models are fitted with twin Rolls-Royce RTM322 engines.

HYDRA ROCKET LAUNCHER**SPECIFICATIONS**

CREW: 2
COUNTRY OF ORIGIN: USA
COMMISSIONED: 1997
RANGE: 1,180 MILES (1,900km)
TOP SPEED: 173mph (279km/h)
ENGINE: 2x TURBOSHAFT T700-GE-701C
WEAPONS: 30mm M230 CHAIN GUN, HELLFIRE MISSILES, 70mm ROCKETS

HELLFIRE MISSILES

F-35 LIGHTNING II

This supersonic stealth strike aircraft is the world’s most advanced fighter

The Lockheed Martin’s F-35 Lightning II Joint Strike Fighter (JSF), meanwhile, has a maximum speed of Mach 1.6. There are three variants: the F-35A, F-35B and F-35C, each with slightly different abilities. While it can’t officially supercruise, it can maintain a speed of Mach 1.2 without its afterburners for a brief time, and like the F-22 it’s designed to scatter radar waves and remain invisible on radar screens. It’s outfitted with a single Pratt & Whitney F135 engine and, despite the delays, it’s been described as one of the most advanced aircraft in the world. It’s more suited to air-to-ground combat than the F-22, being able to carry more powerful bombs. Although it flew for the first time in 2006, it didn’t enter service until 2015.

“THE F-35 IS ONE OF THE MOST ADVANCED AIRCRAFT IN THE WORLD”

ADVANCED ELECTRONIC WARFARE
Pilots in the F-35 can track enemy forces, jam radars and more with its high-tech capabilities.

FIBRE MAT
The plane is built with absorbent materials, such as fibre mat, to give it a low radar profile.



The F-35 is the newest American fifth-generation fighter

SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: USA
COMMISSIONED: 2015
RANGE: 1,367mph (2,200km)
TOP SPEED: 1,227mph (MACH 1.6)
ENGINE: PRATT & WHITNEY F135-PW-100
TURBOFAN ENGINE
WEAPONS: 25mm GAU-22/A CANNON
2x AIM-120C/D AIR-TO-AIR MISSILES
2x 2,000lb GBU-31 JDAM GUIDED BOMBS

SUPERSONIC

The single F135 engine enables the F-35 to reach up to Mach 1.6.

ENGINE INTAKE

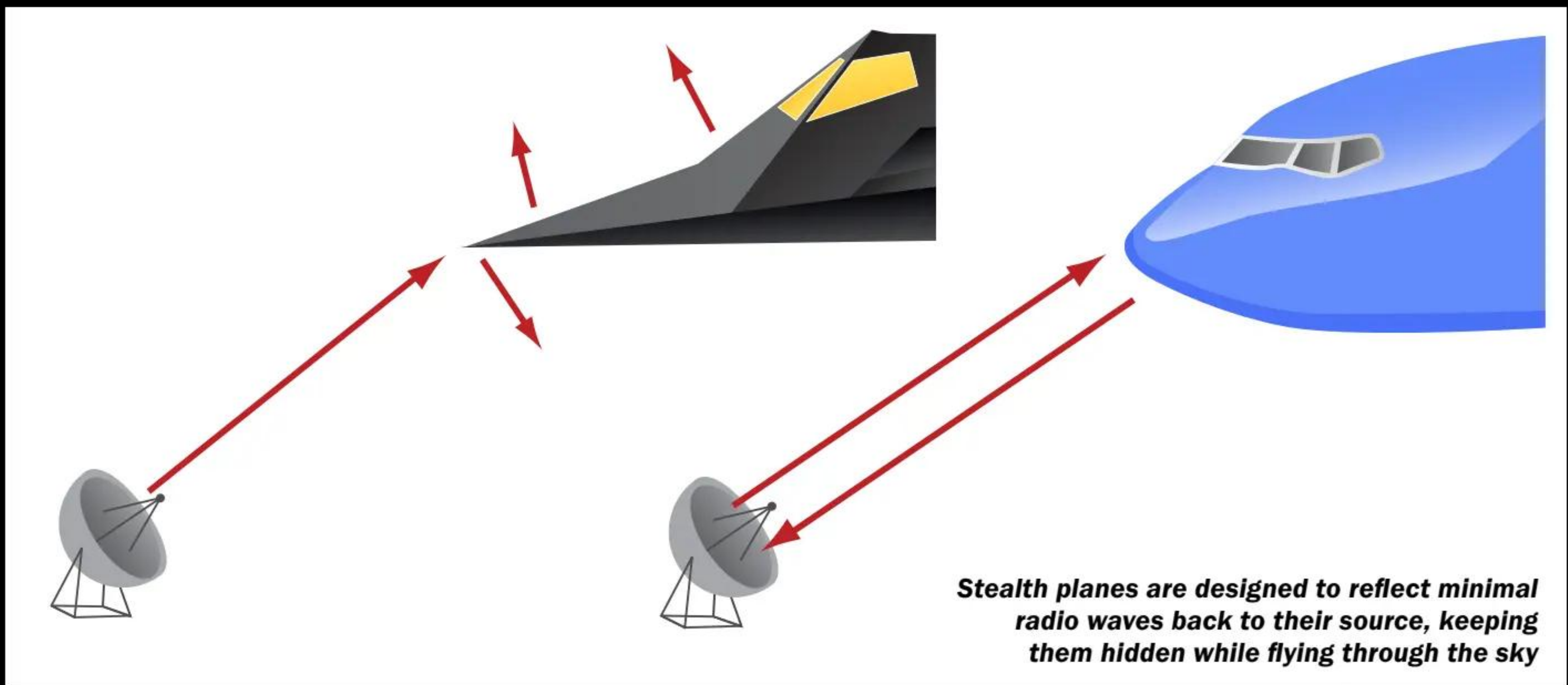
The air intakes for the engine are designed to be hard to spot by radar.

VERTICAL LANDING

The F-35B variant can take off, hover and land vertically by rotating its engine downwards.

STEALTH TECHNOLOGY

Radar systems are able to see planes by bouncing radio waves off them then measuring the time taken for the reflection to return to determine the position of the aircraft. But what if the waves never return? That's the basic idea around stealth planes, which are designed to reflect or scatter waves so that they go undetected. Some do this with their design, using conjoined edges and smooth surfaces to achieve a low RCS – the lower the better. Others use materials that absorb radar signals in order to produce a similar effect. While some stealth aircraft have a lower RCS than others, each fifth-generation fighter is able to keep itself hidden before it's time to strike.



21st Century

TEMPEST

This sixth-generation stealth combat fighter is being built by a three-nation partnership

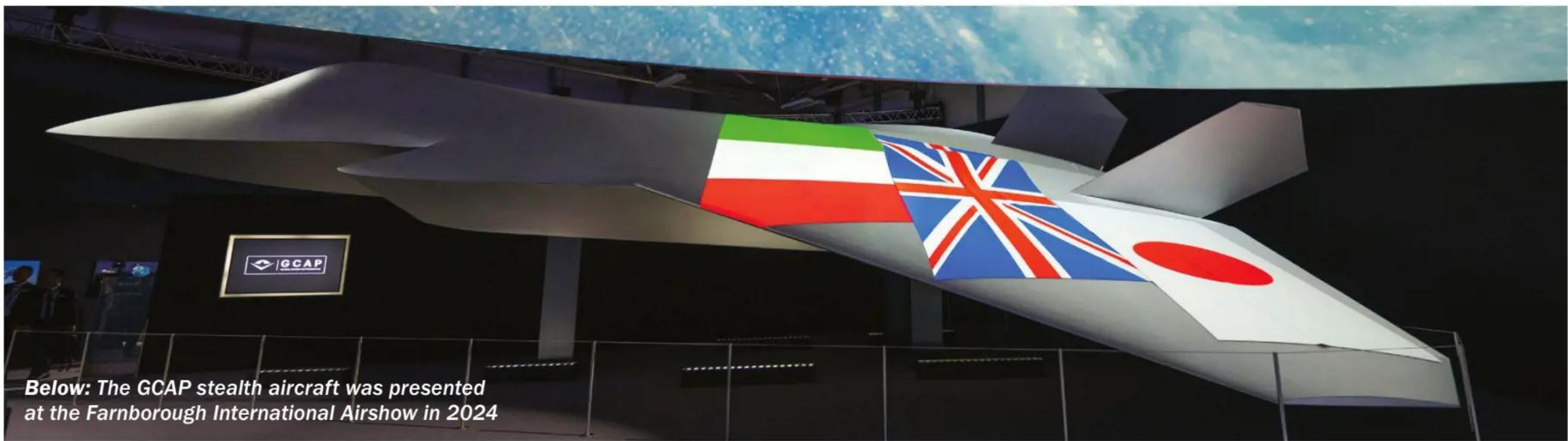
The Global Combat Air Programme (GCAP) is an international partnership between the governments of the UK, Italy and Japan. These countries are collaborating to build their answer to the next generation of stealth jets, named Tempest. The final product, which is due to enter service and replace the Typhoon fighter aircraft in 2035, will be shared across these countries' militaries. Tempest development is led by aerospace and defence companies BAE Systems (UK), Leonardo (Italy) and Mitsubishi Heavy Industries (Japan). As part of the GCAP, digital engineers have a significant role in testing and developing the next-generation stealth jet. Manufacturers are working to produce one of the most advanced, adaptable and connected fighter jets in the world. The resulting Tempest stealth fighter will be used to maintain security in the Euro-Atlantic and Indo-Pacific, while signing the GCAP treaty tightens the partnership of these nations.

EFFICIENT FLYING
The wing shape is called a delta planform. This means they are triangular when viewed from above. This is the optimal shape for supersonic speed due to its aerodynamics.

INTERNAL PAYLOADS
Tempest will be able to carry weapons internally, better protecting them from supersonic forces and preserving a stealthy shape.

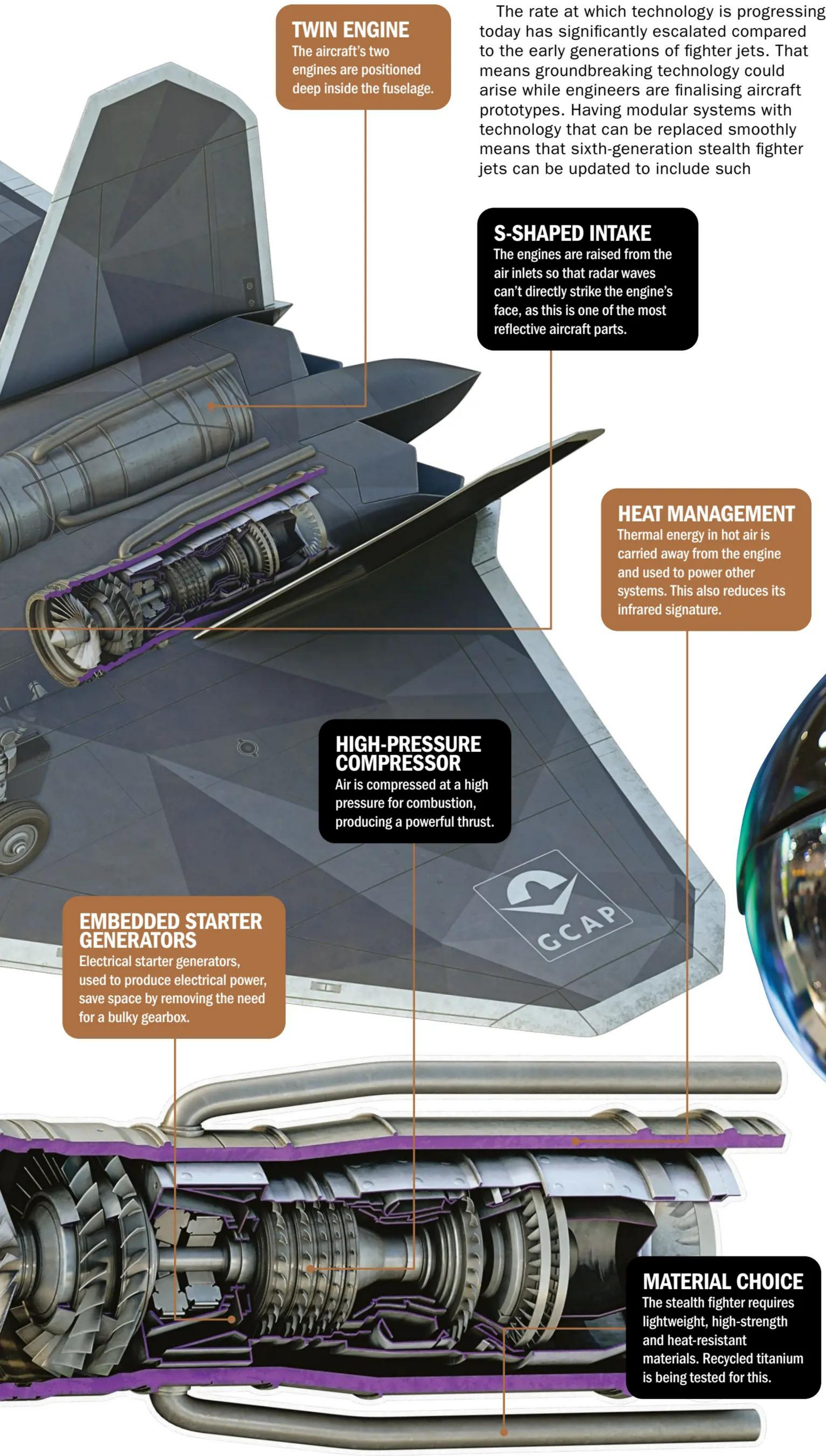
RECYCLED BODY
High-quality steel, aluminium and titanium from old Tornado aircraft have been powdered and 3D printed to make Tempest components.

FAN STAGES
Large bypass fans compress air for thrust and cooling. The blades are shaped to reduce radar reflections and to work when airflow is uneven during manoeuvres.



Below: The GCAP stealth aircraft was presented at the Farnborough International Airshow in 2024





TWIN ENGINE

The aircraft's two engines are positioned deep inside the fuselage.

The rate at which technology is progressing today has significantly escalated compared to the early generations of fighter jets. That means groundbreaking technology could arise while engineers are finalising aircraft prototypes. Having modular systems with technology that can be replaced smoothly means that sixth-generation stealth fighter jets can be updated to include such

S-SHAPED INTAKE

The engines are raised from the air inlets so that radar waves can't directly strike the engine's face, as this is one of the most reflective aircraft parts.

HEAT MANAGEMENT

Thermal energy in hot air is carried away from the engine and used to power other systems. This also reduces its infrared signature.

HIGH-PRESSURE COMPRESSOR

Air is compressed at a high pressure for combustion, producing a powerful thrust.

EMBEDDED STARTER GENERATORS

Electrical starter generators, used to produce electrical power, save space by removing the need for a bulky gearbox.

MATERIAL CHOICE

The stealth fighter requires lightweight, high-strength and heat-resistant materials. Recycled titanium is being tested for this.

upgrades. This relates to both software and hardware. Physically being able to take off a module and replace it with the latest payload or flight feature means that, between flights, the same aircraft can be transformed and updated. Software-wise, pilots can be equipped with the most effective data and digital tools almost as seamlessly as a computer software update.

HOLOGRAPHIC HANDLING

As the new generation of stealth fighter jets adapt to a new era of aerial combat, the methods pilots use to fly aircraft is changing. In the Tempest, for example, technology not too dissimilar to that of video games is being used to navigate the skies. The jet is compatible with a bespoke augmented-reality helmet that projects data from the craft's surroundings and virtual controls into the visor instead of hardware control and display systems. Primary control sticks will still be incorporated into the cockpit, but the jet can change its software and hardware easily depending on the mission and the functions required. In addition, sensors in the cockpit track the gestures of the pilot, as well as their eye movements, so that onboard computers know what the pilot is seeing and can analyse patterns that signify fatigue and mental stress.



Above: Advanced fighter pilot helmets use cameras to embed data and images onto the inside of the visor in real time

ANTI-DRONE GUN

How these devices intercept and disable unmanned aerial vehicles

Drones are becoming increasingly popular in many industries. They're especially common for recreation and film-making. These small, light aircraft are operated remotely, without a human pilot on board. This means they can be perfect tools for search and rescue, surveillance and aerial photography. However, their capabilities have also been adopted as powerful tools of war. Without placing a soldier in danger, drones can fly over war zones and be used to spy on the enemy, drop explosives or detonate as explosive devices themselves. Drones can be produced and deployed in large numbers, so police and militaries now require Counter Uncrewed Aerial System (C-UAS) devices, or anti-drone guns. These guns can stop drones in two main ways: by interrupting communications with their base or by physically disabling the apparatus. This means that from the ground, anti-drone guns can prevent spying, military attacks and terrorist activity.

Some anti-drone guns are as small as pistols and release electromagnetic energy waves. These damage the drones' critical electronic components and cause them to malfunction. These don't shoot physical ammunition, but the location the drone is targeted over may need consideration, as the disabled drone may fall out of the sky. One event that saw an international demonstration of a country's anti-drone technology was during the 2024 Paris Olympics Games in France. These high-profile and international events are high-risk for terrorist attacks. Before the Olympics began, a demonstration of their HELMA-P anti-drone laser system took place to show the world that



Small anti-drone guns have a range over 100 metres

the Games would be safe from such a threat. HELMA-P uses a high-energy laser beam to disable a drone's electronics, and sensors to detect, track and neutralise them.

AUTOMATED ATTACK

As anti-drone guns get smarter, these weapons no longer need to rely on the aiming precision of their human operator. Systems such as the British Army's SmartShooter SMASH Smart Weapon Sight Fire Control System enables these weapons to recognise a drone, track its movements and lock in on it to successfully target it when shooting. Even when the person holding the gun is on the move, the smart target-locking system remains steady. This smart technology can be fitted to existing guns, turning them into efficient anti-drone weaponry. It has proven successful on rifles such as the SA80 A3 assault rifle.



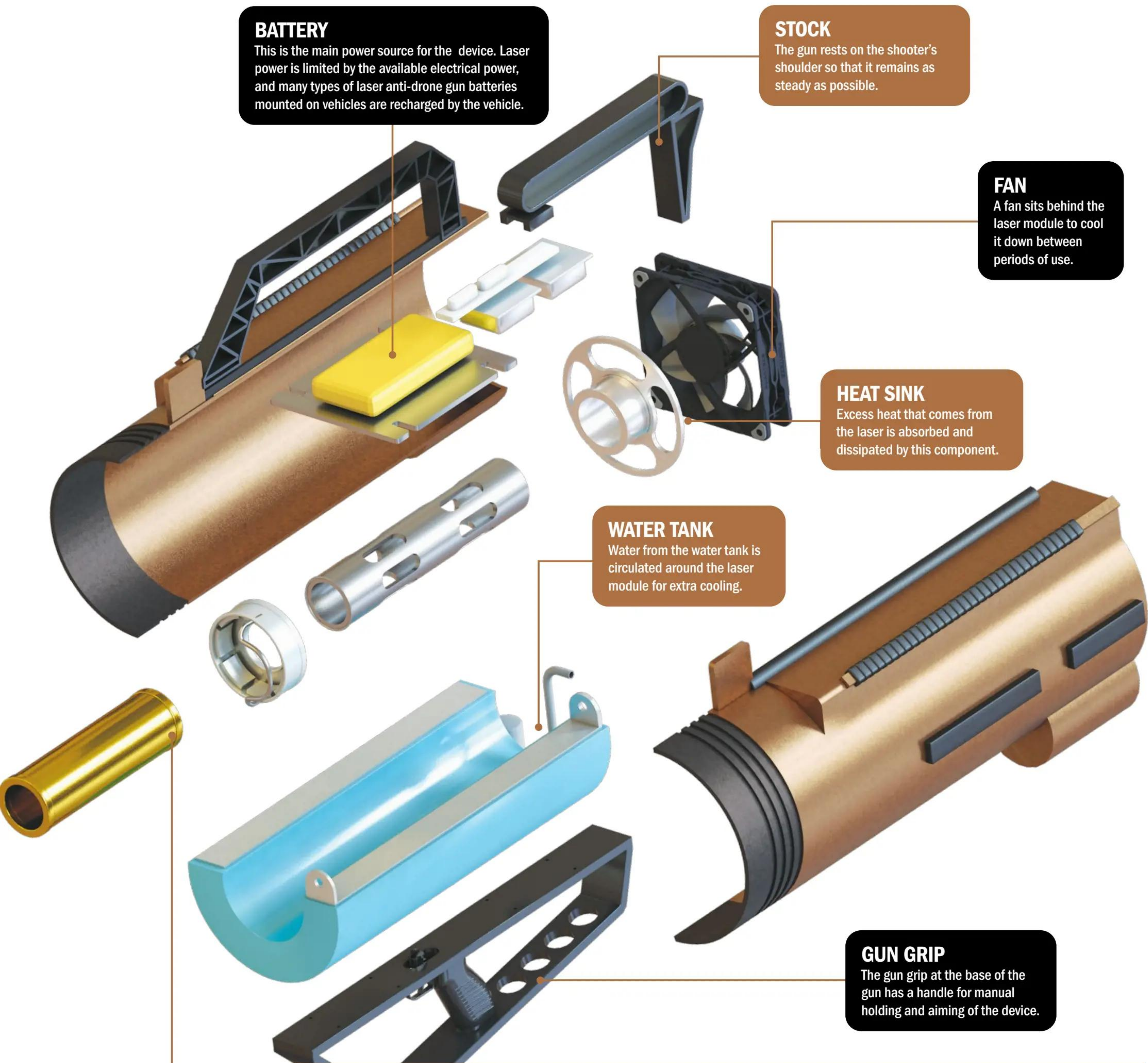
Above: Regular guns can be fitted with automatic drone-tracking capabilities

"FROM THE GROUND, ANTI-DRONE GUNS CAN PREVENT SPYING, MILITARY ATTACKS AND TERRORIST ACTIVITY"

4 PLANO-CONVEX LENS
This lens concentrates the laser into a focused, narrower beam to maintain strength over distance.



3 LENS ADJUSTER
The lens adjuster focuses the generated laser beam at different ranges for accurate shooting.



BATTERY

This is the main power source for the device. Laser power is limited by the available electrical power, and many types of laser anti-drone gun batteries mounted on vehicles are recharged by the vehicle.

STOCK

The gun rests on the shooter's shoulder so that it remains as steady as possible.

FAN

A fan sits behind the laser module to cool it down between periods of use.

HEAT SINK

Excess heat that comes from the laser is absorbed and dissipated by this component.

WATER TANK

Water from the water tank is circulated around the laser module for extra cooling.

GUN GRIP

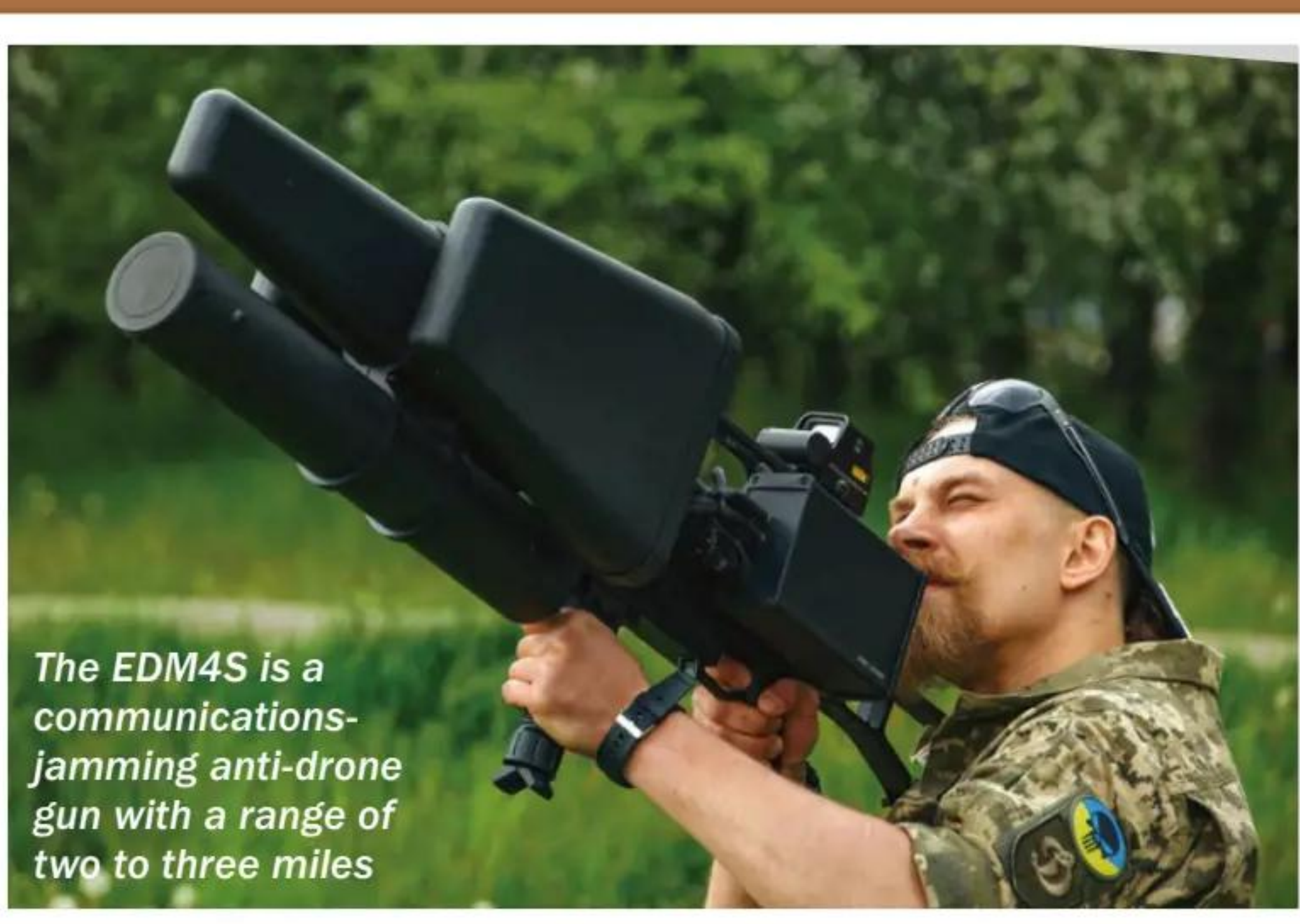
The gun grip at the base of the gun has a handle for manual holding and aiming of the device.

2 LASER MODULE

This is the core component, which generates a focused infrared beam of energy to disable a drone's sensors and hardware.

INTERCEPTION TYPES

Anti-drone technology is split into detection and interception. The detection of drones uses thermal imaging, which picks up on thermal trace from the drone's engines and batteries, or radio frequency sensors that can pick out drones' operating signals in a frequency range from 70 megahertz to 6.0 gigahertz. To intercept a drone, an anti-drone gun can use jamming, a net or kinetic countermeasures. Jamming guns work by disrupting the communications of the detected drone. They send out powerful radio signals that are the same frequencies the drone uses, overwhelming the drone's receiver. A drone's GPS can also be impacted by jamming. As a result, a drone may hover in place, return home or lose control of its flight and land below where it was attacked. Net drone guns shoot a net that will physically catch a drone without destroying it. Finally, kinetic countermeasures involve physically damaging the drone's equipment to take it down.



The EDM4S is a communications-jamming anti-drone gun with a range of two to three miles

Illustration: Adrian Mann

..... Ancient ROMAN WARSHIP

Originally a Carthaginian design, the quinquereme dominated the Mediterranean

The First Punic War was the first of three wars fought between the Roman Republic and the Carthaginian Empire. It broke out in 264 BCE when Carthage intervened in a dispute between the cities of Messina and Syracuse on the island of Sicily, a Carthaginian province. Rome got involved on behalf of Messina while Carthage supported Syracuse, triggering a bitter war for control over Sicily that lasted over 20 years.

While Carthage had a powerful navy that dominated the waves, it was the first time that Rome was required to build one. It was said by Polybius, a Greek historian, that the Romans did not know how to build warships and so they looked to a Carthaginian ship – a quinquereme – that had washed ashore. In just a few weeks, they built a fleet of 100 quinqueremes (as well as 20 triremes) based on this ship.

The Romans finally scored their first naval victory at the Battle of Mylae in 260 BCE, during which they managed to destroy or capture 44 Carthaginian ships.

Even though other vessels were used, the quinquereme became the main warship used by the Romans during the Punic Wars. These ships were evolved over time and Rome eventually emerged victorious, with the Punic Wars culminating in the destruction of Carthage in 146 BCE.

The quinquereme helped the Romans gain supremacy over the Mediterranean and played a major role in their naval battles for centuries. However, these ships were superseded by smaller ones after the Battle of Actium in 31 BCE, a naval battle that took place at the end of the Roman Republic. We have chosen to look at an example of an early version of the quinquereme, although particular details of the ship still remain unclear.

“THE ROMANS SCORED THEIR FIRST NAVAL VICTORY AT THE BATTLE OF MYLAE”

THE CORVUS

Roman quinqueremes were vulnerable to the ramming ability and speed of the Carthaginian ships, especially as their crews were less experienced. To solve this, the Romans created the corvus, a bridge with an iron spike that could be lowered and locked onto an enemy ship, allowing their infantry to cross over and attack. Although successful, the weight of the corvus made the ships unstable and so they were eventually abandoned.

ARMED FORCES

The size of the ship enabled it to carry a large naval infantry force, with between 40 to 120 marines onboard at one time. As the quinquereme was developed, artillery weapons such as catapults and ballistae became later additions to the ship, as well as archery towers.

EMBELLISHING THE SHIP

As the quinqueremes became more developed the Romans added more decorative elements. The prow of the ships could be in the shape of a sacred animal or a god, and the sternposts and sternposts decorated with figureheads.

APOTROPAIC EYE

Painted on the prow of quinquereme ships was an apotropaic eye, a divine element that was believed to protect against envy, misfortune and evil spirits. The Romans also thought that the eye would help keep their ships on course.

THE ROSTRUM

The rostrum was located at the front of the ship and would have been used to ram enemy vessels, either breaking the hull or the oars. It could be positioned either on the waterline or underwater, and as the quinquereme was a heavy ship it had the potential to sink an enemy vessel on impact.

THE MAINSAIL

Unfortunately, the specific details of quinqueremes remain unclear, although they definitely had at least one or even two sails. It is likely that the mainsail was eventually decorated with the SPQR emblem that was adopted during the Late Republic, around the 1st century BCE.

STRONG AND STEADY

The Roman quinqueremes were bigger than those built by the Carthaginians – according to Greek historian Polybius they were 45m long and 5m wide. Although this made the quinqueremes more difficult to manoeuvre it also made them more stable, particularly in bad weather conditions.

SIEGE VESSELS

If siege equipment was needed, two quinquereme ships could be joined together so that siege towers and large catapults could be ferried to the target. This was done during the Siege of Syracuse in 213 BCE, which took place during the Second Punic War.

CREW ARRANGEMENT

Quinqueremes got their name because they were operated by oarsmen arranged in groups of five. It is thought that there were three banks of oars, around 90 on each side, with pairs of men on the top two rows and one man on the bottom.

TIGHT ON SPACE

The ship was designed to have up to 300 rowers onboard at once. This meant that often there was little to no room to carry any food or even the amount of water that the rowers needed – up to three litres a day per man. The crew would have likely eaten a diet consisting of hard biscuits, which did not spoil easily.

THE MARY ROSE

Henry VIII’s flagship is famed for its demise, but the subject of the largest maritime archaeological excavation ever undertaken has much more to it than meets the eye

SPECIFICATIONS

CREW: 415
COUNTRY OF ORIGIN: ENGLAND
COMMISSIONED: 1511
LENGTH: 110ft (33.65m)
BEAM: 25.57ft (7.80m)
WEAPONS: 2 TOP GUNS; 30x SWIVEL GUNS;
15x BRONZE MUZZLELOADER CANNON; 24x
IRON BREECHLOADER CANNON

ANTI-BOARDING MEASURES

Spot finds of archery equipment on the upper deck in the waist of the ship indicate that archers were moving about during the battle in anticipation of close-quarters actions and anti-boarding manoeuvres.

NETTING

Netting strung above the upper deck between the castles was a deterrent to boarders but also prevented the crew escaping as the ship sank. Of the 500 men onboard, only between 30 and 35 survived.

FORWARD-FIRING CAPABILITIES

Due to the shape of the hull, the ability to fire ahead was limited. The main forward-firing capability was through cast bronze culverins on the castle deck facing forward at the front of the sterncastle.

BLINDS

Some of the ‘blinds’ in the waist of the ship on the upper deck were removable so archers and soldiers with handguns could be positioned there.

GUN DECK FIREPOWER

Seven broadside guns were stationed at lidded gun ports supporting a mixture of cast-bronze muzzleloaders and wrought-iron breechloaders. During the excavation, all were found still sitting on their wooden carriages.

SHOT LOCKERS

The three main shot lockers. 1,248 cast iron shot, 387 stone shot, composite shot and canister shot have been found during excavations.

REASON FOR SINKING

The Mary Rose sank due to water pouring in through her starboard gun ports. The gun port lids were found open and hinged back against the side of the ship.

FOOD STORES

Butchered half carcasses of pork (headless and split down the centre) were found in one area. The position they were in suggested that they had been hung and were probably salted.

LOGS

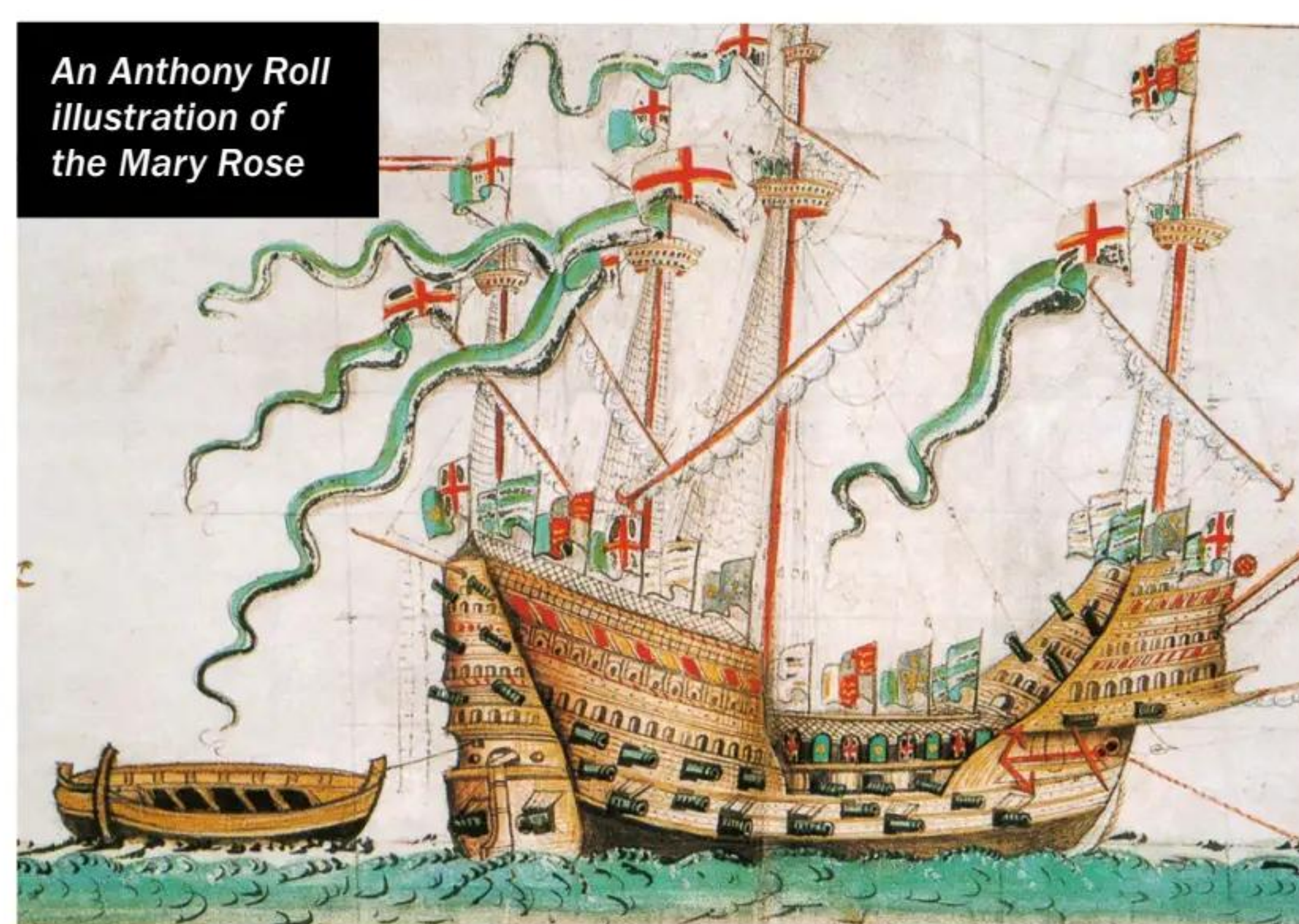
Substantial amounts of quartered logs were found, which was a store of wood for the Mary Rose.

Henry VIII came to the throne in 1509; a year later work began on two new ships. It is believed that the Mary Rose was one. During his reign, Henry increased the British fleet from four vessels to 58, and 20 of these were great ships (four-masted warships). The Mary Rose was the second largest of these. Its lifespan somewhat mirrors the reign of the king (1509–47), as it sank on 19 July 1545 defending the English coast from a French invasion force larger than the Spanish Armada.

This was a short period of intense change, with a dramatic shift in

the types of guns and the nature of warfare. Ships used to employ the tactic of very short-range bombardments followed by boarding, but the change brought longer-range warfare where the ships would move closer. There was still some close-quarters conflict, as demonstrated by the numbers of longbows and staff weapons carried onboard. Ships like it, with the capability of at least a partial broadside, marked the beginning of a type of warfare that was to endure until the middle of the 19th century. The Mary Rose, with her incendiary darts, longbows and long-range culverins, was indeed a ship of a transitional era.

An Anthony Roll illustration of the Mary Rose



CAST-IRON GUNS

Four of the 20 'hailshot pieces' listed for the ship were found. These guns are the first evidence of the mass production of cast-iron guns in England. With a rectangular bore they fired small iron dice at short range.

GUN DECK CABINS

The main gun deck was not only a fighting area. Cabins for the navigator, surgeon and carpenter were also located on this deck.

ARCHERS, BOWS AND ARROWS

For the battle, chests of bows and arrows had been taken up from the main archery store on the orlop deck in the stern to the upper deck just inside the sterncastle, the muster station for the archers.

MATCHLOCK ARQUEBUSES

Parts of five of the 50 handguns listed for the ship were found. Three are snap matchlock arquebuses imported from the town of Gardone in Italy. Historical documents verify that 1,500 were imported in 1544 in preparation for the war with France.

IRON GUNS

The ship represented the most advanced weapons systems of its time. Breechloading, the iron guns could fire solid limestone shot or, at closer range, canisters filled with flakes of flint or pebbles.

INCENDIARY DARTS

Three long darts with incendiary sacks bound close to their heads were found beside a large gun on the main deck.

SHIP'S OVENS

The galley consisted of two brick 'ovens' located in the centre of the ship in the hold. Copper alloy cauldrons enabled the cooking of a large amount of broth, while haunches of meat could be dangle-roasted in front of the oven.

ENGAGING THE FRENCH

The Mary Rose did engage with the French; some of her guns had been fired and one was being reloaded as the ship sank.

UNIQUE GUN SHIELDS

Remains of eight shields with breechloading handguns mounted centrally within them were found in store on the orlop deck. These have never been known in a combat situation before and were previously thought to be the preserve of the King's Royal Guards.

Early Modern

PORTUGUESE NAU

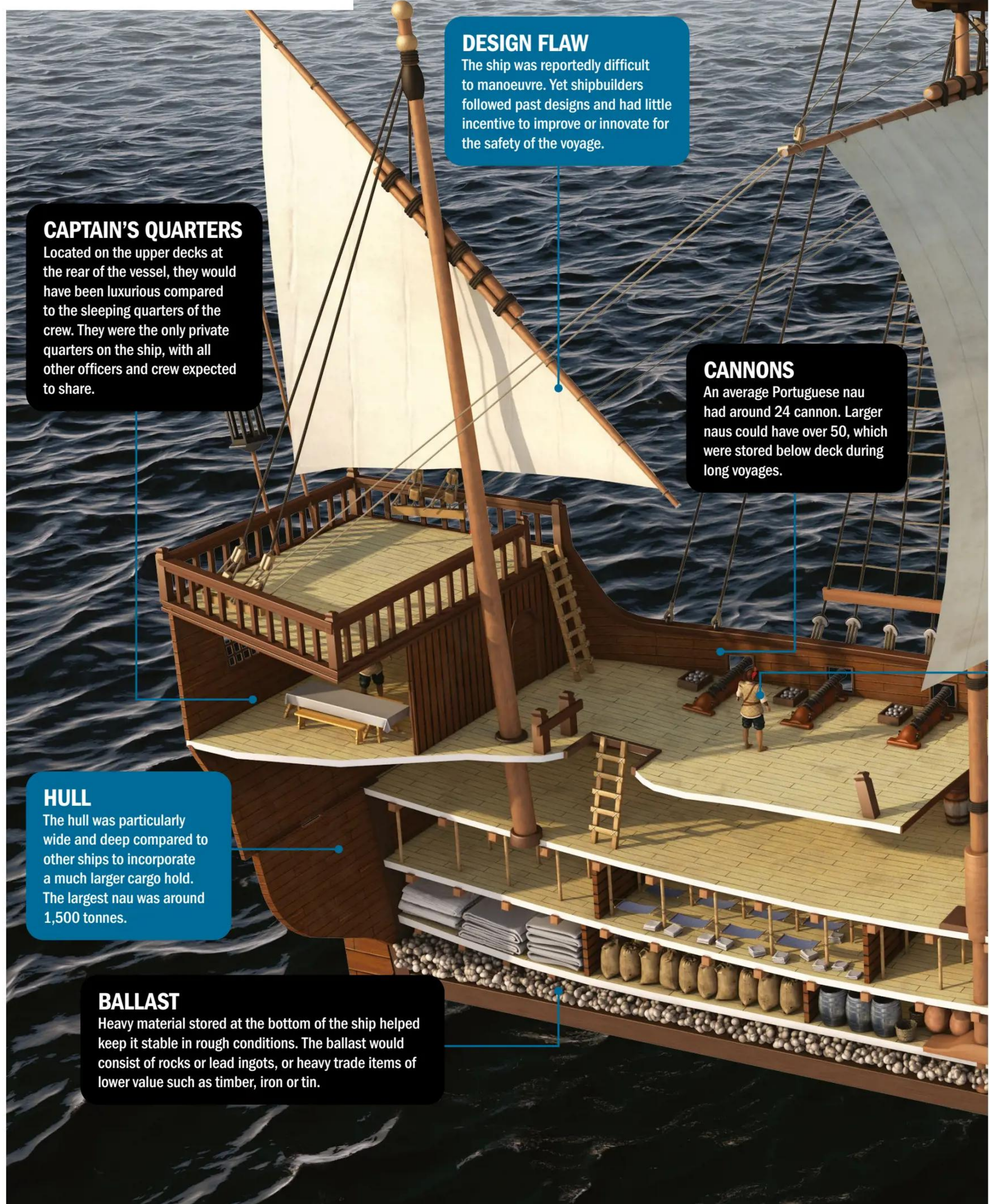
These vessels projected Lisbon's economic and military power across the globe

In 1498, the Portuguese explorer Vasco da Gama reached the shores of India. His voyage opened up a previously unknown maritime route via the Cape of Good Hope and began a new chapter in the spice trade. Over the following centuries this route allowed Portugal to trade directly with the spice merchants of Asia in territories such as India, China and the Spice Islands. Until the 17th century, when their dominance of the African route was challenged by the Netherlands, Portuguese merchant ships known as naus (called carracks in other countries) made the long voyage, their hulls laden with spices.

The nau was specifically designed with these long voyages in mind and their hulls were much wider and larger than previous ships to allow for the added cargo. This also proved useful when carrying supplies for the voyages, which were far longer than any undertaken in previous centuries. Over the years the naus grew in size, with some having four masts instead of three.

The ship was eventually replaced by the galleon, which drew on the former's design but was much more heavily armed and was used primarily as a warship. The galleon's cargo capacity never quite reached that of the nau and they continued to be used for some time afterward. It was an important vessel that helped start the Age of Exploration and further the global spice trade.

**"THE SHIP WAS
EVENTUALLY REPLACED
BY THE GALLEON"**



DESIGN FLAW

The ship was reportedly difficult to manoeuvre. Yet shipbuilders followed past designs and had little incentive to improve or innovate for the safety of the voyage.

CAPTAIN'S QUARTERS

Located on the upper decks at the rear of the vessel, they would have been luxurious compared to the sleeping quarters of the crew. They were the only private quarters on the ship, with all other officers and crew expected to share.

CANNONS

An average Portuguese nau had around 24 cannon. Larger naus could have over 50, which were stored below deck during long voyages.

HULL

The hull was particularly wide and deep compared to other ships to incorporate a much larger cargo hold. The largest nau was around 1,500 tonnes.

BALLAST

Heavy material stored at the bottom of the ship helped keep it stable in rough conditions. The ballast would consist of rocks or lead ingots, or heavy trade items of lower value such as timber, iron or tin.

MASTS

A Portuguese nau would typically have three or four masts, with square and lateen (triangular) sails. These large Portuguese vessels were much taller than other nations' ships built during the same period.



The nau helped open up new trading routes with Asia

CREW

Some of these ships were crewed by up to 200 men. Portuguese diplomat Dom Antonio de Ataide stated that the ideal number was "60 sailors, 60 grumetes [young apprentice sailors], four pages or cabin-boys and 26 gunners". Some larger naus were said to have around 600 sailors.

CREW QUARTERS

The living conditions were extremely cramped. Each crew member had very little sleeping space and mortality rates among them could be high. Conditions during these voyages were said to be little better than those of later slave trading ships.

CARGO

A large Portuguese nau travelling from Asia could carry a cargo equivalent to five or six galiots (smaller ships), which is equivalent to between 1,500 and 2,000 tonnes. Among the valuable items would be spices such as pepper, cloves, nutmeg and cinnamon.

CONSTRUCTION

During the Middle Ages ships were built by layering planks around the keel until the hull took shape. But the nau, being much larger, was constructed using the carvel technique in which the frame was built first and the planks laid end to end.

HMS VICTORY

One of the most famous ships of all time, HMS Victory was instrumental in ensuring British naval supremacy during the Napoleonic Wars

The only surviving warship to have fought in the American War of Independence, the French Revolutionary War and the Napoleonic wars, the HMS Victory is one of the most famous British ships ever to be built. It was an imposing first rate ship of the line in service with the Royal Navy from 1778, though it was originally launched in 1765.

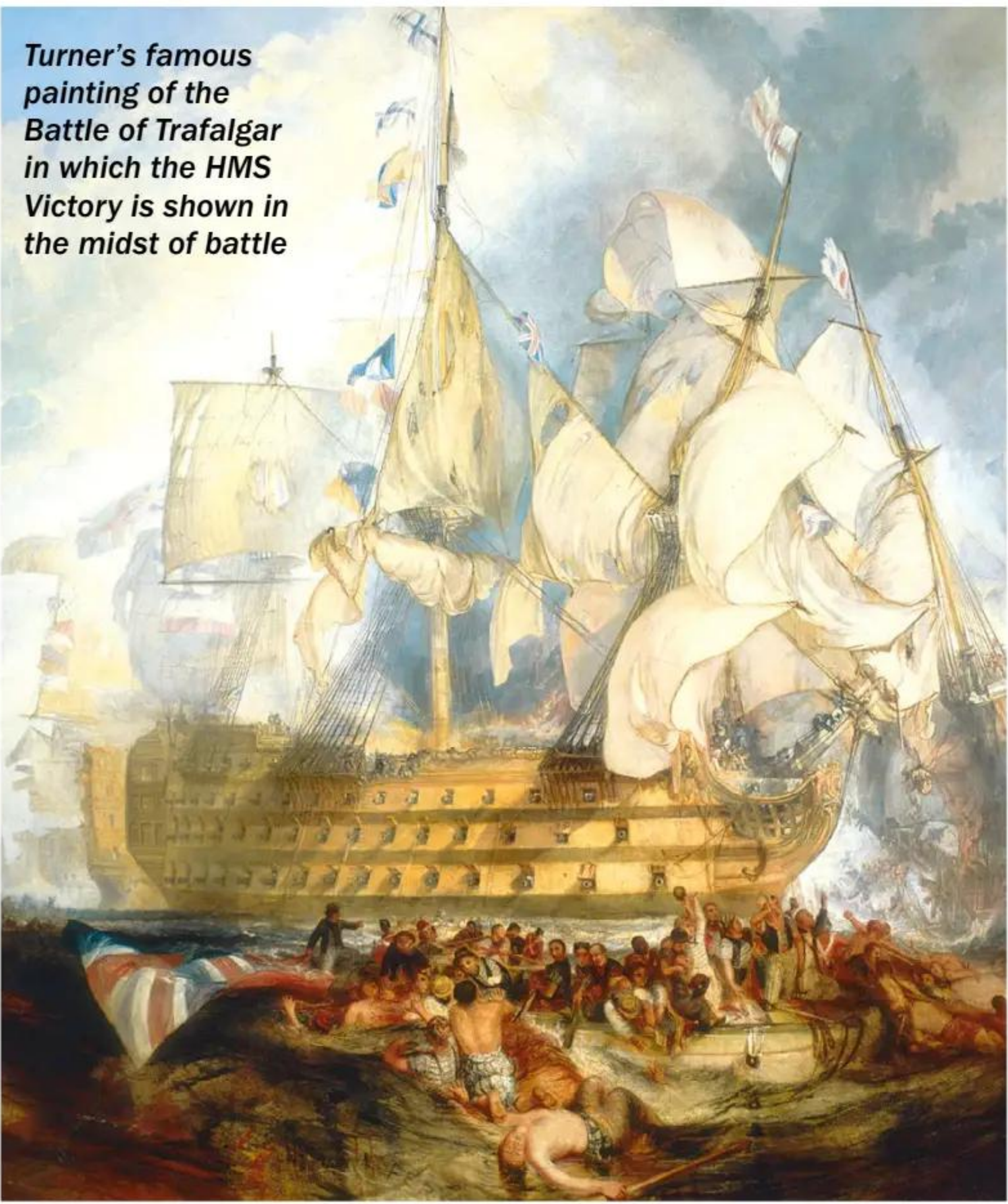
Victory was an oceanic behemoth, fitted with three massive gundecks, 104 multiple-ton cannons, a cavernous magazine and a crew of over 800 men and officers. It was a vessel capable of blowing even the largest enemy man-of-wars out of the water with magnificent ferocity and range, while also outrunning and outmanoeuvring other aggressors.

The warship's most famous wartime service was as Vice-Admiral Horatio Lord Nelson's flagship during the epic naval battle off the Cape of Trafalgar. Here, HMS Victory partook in the last great line-based conflict of the age, one in which it helped to grant Nelson a decisive victory over the French and Spanish, at the cost of his own life.

SPECIFICATIONS

CREW: OVER 800
COUNTRY OF ORIGIN: GREAT BRITAIN
COMMISSIONED: 1778
SPEED: 9kts (17km/h)
LENGTH: 227ft (69m)
BEAM: 51ft (15.5m)
DISPLACEMENT: 3,500 TONS
PROPULSION: SAILS - 5,440m²
WEAPONS: 104 GUNS

Turner's famous painting of the Battle of Trafalgar in which the HMS Victory is shown in the midst of battle



SAILS

The HMS Victory is a fully rigged ship, with three sets of square sails covering 5,440m². The breadth of the Victory's sails allowed it to sport a maximum top speed of nine knots when operational, which was for the time very impressive considering its size and weight. During the 18th and 19th centuries a fully rigged ship necessitated three or more masts each of which with square rigging. At full flight the Victory could spread a maximum of 37 sails at one time and could carry 23 spares.

CREW

There were over 800 people on board the HMS Victory, including gunners, marines, warrant officers and powder monkeys among many others. Life on board was hard for the sailors, who were paid very little for their services and received poor food and little water. Disease was rife too, and punishments for drunkenness, fighting, desertion and mutiny ranged from flogging to hanging.



MASTS

The HMS Victory sported a bowsprit (the pole extending beyond the ship's head), fore mast, main mast, mizzen mast and main yard. A total of 26 miles (41.9km) of cordage, as well as 768 elm and ash blocks, were used to rig the ship.

DECKS

The HMS Victory had seven main decks, including: the hold, orlop, lower gundeck, middle gundeck, upper gundeck, quarterdeck and poop deck.



(A) THE HULL

The hull was the largest storage area on the ship where up to six months of food and drink could be stored, as well as any excess supplies.

(B) THE ORLOP

The only other deck below the waterline, the orlop was another storage area and also habitation deck for certain crew members such as the purser.

(C) THE GUNDECKS

Housed the majority of the Victory's cannons, with a tiered arrangement from top to bottom (largest cannons on the bottom, smallest on the top). These decks also housed the majority of the crew and Royal Marines, sleeping in hammocks suspended from battens fixed to overhead beams. The lower gundeck also acted as mess deck, the space where the crew would live and eat.

(D) THE QUARTERDECK

The nerve centre of the ship, where its commander dictated its manoeuvres and actions often under heavy gunfire from rival vessels.

(E) THE POOP DECK

Located at the stern, this short deck takes its name from the Latin word puppis, which literally means 'after deck' or 'rear deck'. This deck was mainly used for signalling, but also gave some protection to the man helming the ship's wheel.

CANNON

As a first rate ship of the line, the Victory was a three-gundeck warship with over 100 guns. In fact, the Victory was fitted with 104 cannon: 30 x 2.75 ton long pattern 32-pounders on the gundeck, 28 x 2.5 ton long 12-pounders on the middle gundeck, 30 x 1.7 ton short 12-pounders on the upper gundeck, 12 x 1.7 ton short 12-pounders on the quarterdeck, and 2 x medium 12-pounders and 2 x 68-pounder carronades on the forecastle.



MAN-OF-WAR

Highly versatile and powerful ships capable of trade, diplomacy and combat, the man-of-war was the most prominent of armed ships for centuries

Spanning a variety of ship designs from the 1500s to 1850, but typified by the galleon and ship of the line class of vessels, man-of-war ships were exemplars of shipbuilding expertise, delivering high manoeuvrability, storage capacity and firepower. They worked by taking the roundship and cog ship designs that had been the staple for European trade, transport and warfare since medieval times – both were powered by oars instead of sails – and added multiple masts, decks and cannons as well as more advanced rudder systems.

These additions meant that long-scale voyages were now possible, opening up the largely uncharted world to nations and merchants looking to exploit the Earth's natural resources – opportunities that ultimately led to the great Age of Discovery.

One of the most notable man-of-war ship designs was that devised by Sir John Hawkins, treasurer and controller of the British Royal Navy for Elizabeth I, and a key player in defeating the Spanish Armada in 1588. Hawkins' man-of-war – a name chosen by Henry VIII – was adapted from the Spanish galleon and Portuguese carrack.

The design typically had three masts, was 60 metres long and sported a maximum of 124

cannons, four at the front, eight at the back and 56 on each side. Powered by sail and with a high (for the time) top speed of nine knots (17 kilometres per hour), Hawkins' man-of-war proved to be incredibly successful through the 17th and 18th centuries. It was chosen and adapted by Sir Francis Drake on numerous privateering expeditions.

The last man-of-war ships to be designed were the Grade-1 listed ships of the line in the late 18th and 19th centuries. These were

colossal warships designed to be used in line of battle warfare. They were built primarily for combat and, as demonstrated on Lord Nelson's flagship HMS Victory – which sported a massive array of 32, 24 and 12-pounder cannons – were well armed.

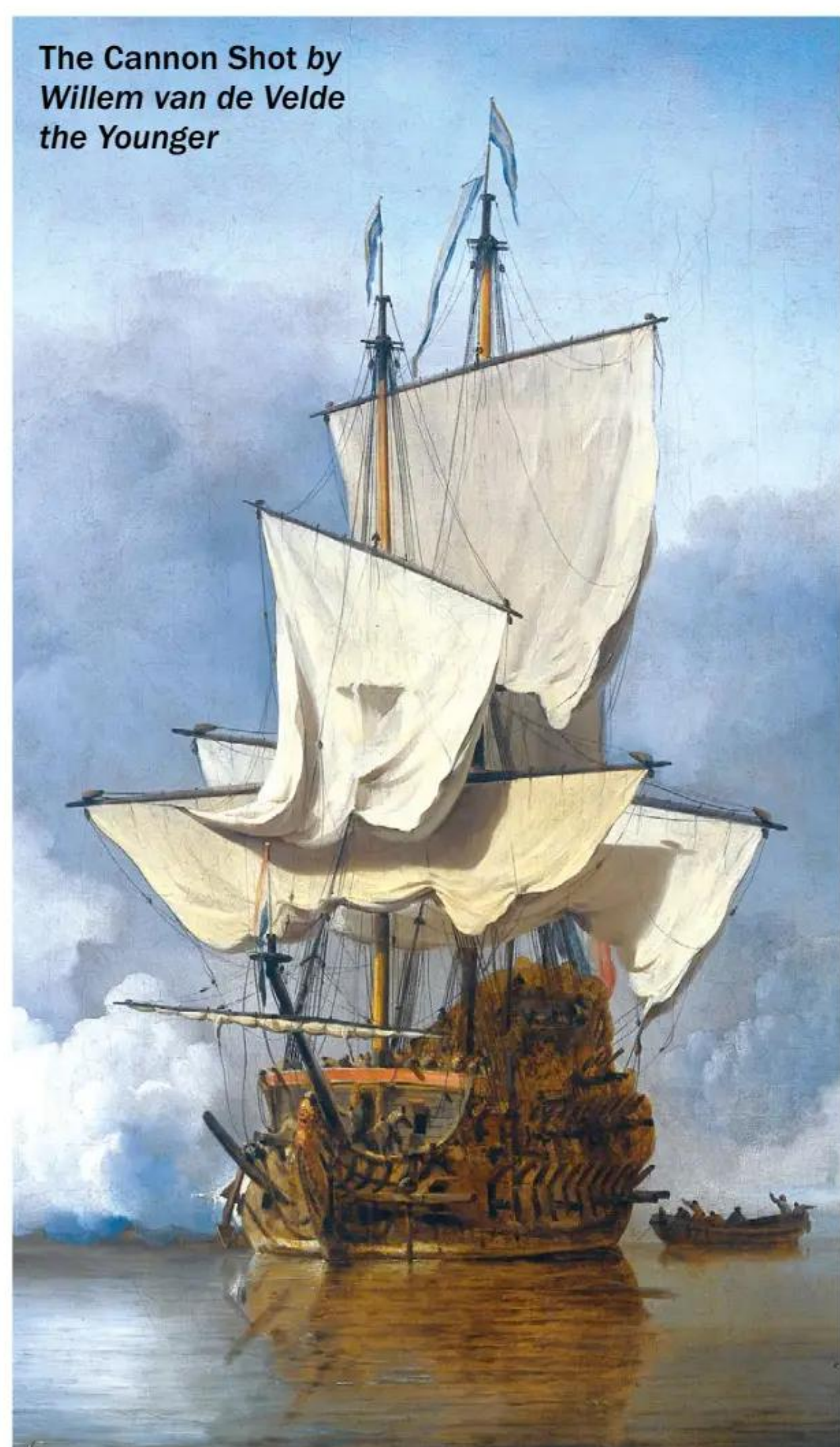
For these first-rate ships of the line, trade was merely an afterthought. They could also be also used for transporting military materiel and manpower, though at the cost of precious speed and agility at sea.

“POWERED BY SAIL, HAWKIN'S MAN-OF-WAR PROVED TO BE SUCCESSFUL THROUGH THE 17TH AND 18TH CENTURIES”

HMS Victory: one of the finest man-of-war examples



The Cannon Shot by Willem van de Velde the Younger



INSIDE THE MAN-OF-WAR

What made this ship design so dominant for so long?

QUARTERDECK

The quarterdeck was the area of the ship where ceremonial functions took place and, while in port, the central control point for all major activities.

MASTS

Common to man-of-war ships was a two- to four-mast design. These included the rear mizzen mast, central main mast and forward foremast. Not all man-of-war ships were square rigged, however.

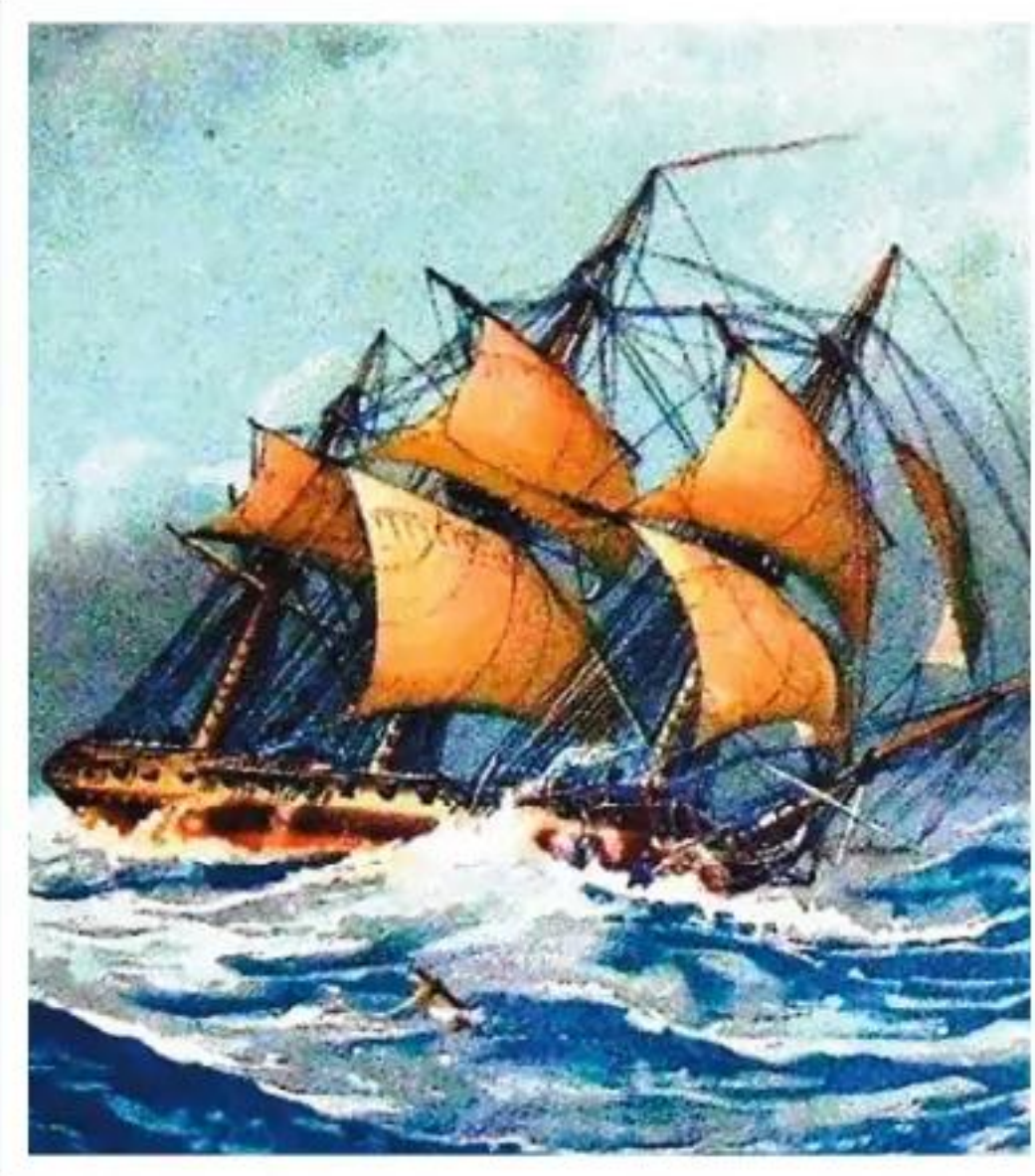


A galleon had plenty of firepower at its disposal

MAN-OF-WAR EVOLUTION

15TH–16TH CENTURY (CARAVEL)

A small, highly manoeuvrable sailing ship developed in the 15th century by the Portuguese, the caravel was the predominant exploration and trading vessel at the time operating in Europe and Africa. It was also used in naval warfare.



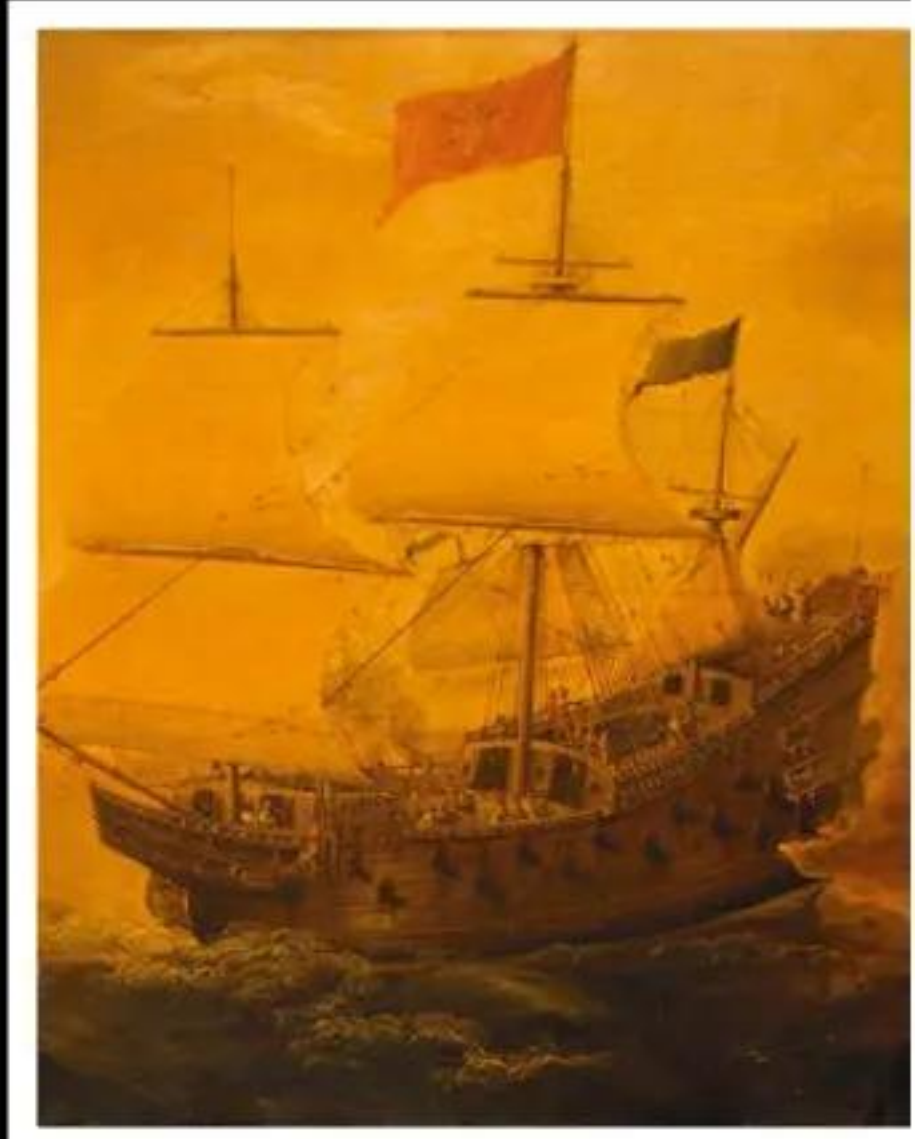
15TH–16TH CENTURY (CARRACK)

A three- or four-masted ship used in Europe, the carrack is considered the forerunner of the great ships of the age of sail. Slightly larger than the caravel, it could undertake longer trading journeys. It was armed with few cannons.



16TH–18TH CENTURY (GALLEON)

Used for both trade and warfare, the galleon evolved from the carrack and included a lowered forecastle and elongated hull for improved stability and manoeuvrability. It had multiple cannons on multiple decks and became a major fighting ship.



17TH–19TH CENTURY (FRIGATE)

Smaller than galleons, frigates were similar to ships of the line but were faster and lightly armed. They were often used for patrolling and escort missions as well as protecting trade ships and trade routes with their cannons and crew.



17TH–19TH CENTURY (SHIP OF THE LINE)

The largest ships built in the great age of sail were ships of the line, massive warships designed to engage with each other in line warfare. These were primarily combat vehicles and sported monumental firepower.



CARGO

Early man-of-war ships were primarily used for exploration and trading even though they were armed. Their cargo was diverse due to the exotic locations they visited and included foodstuffs, precious metals and slaves.

CANNON

While various types of cannons were used on man-of-war ships, 2,540kg demi-cannons were popular thanks to their 490m range and 6in (15cm) calibre. Demi-culverins and sakers were also installed in various quantities.

ANCHOR

Due to the large size of the ships used – with much room needed for their extensive cargo, cannons and crew members – the size of the anchor was also massive, requiring many men to winch it up from the ocean floor.

USS MONITOR

John Ericsson’s ironclad incorporated numerous innovations in warship design, including more than 40 inventions that were eligible for patent

John Ericsson was a genius, whose engineering prowess had contributed to the invention of the screw propeller and the adaptation of the steam engine for use aboard ships. Despite this, the prospects for the success of his proposed ironclad, Monitor, were initially dim.

Ericsson’s fortunes changed when Cornelius Bushnell carried his plans and a scale model of Monitor directly to President Abraham Lincoln, initially bypassing the adversarial Ironclad Board. With Lincoln’s support, the project, which some had dubbed Ericsson’s folly, would take shape after all.

Monitor was a marvel of ingenuity. While the lower hull was in a much more traditional shape, the freeboard distance from the raft-like upper hull to the waterline only measured about two feet, contributing to its shallow draft of just 3.2 metres, which Ericsson believed ideal for operations along the Confederate coastline. He also designed Monitor’s single-cylinder steam engine, which generated a top speed of six knots, adequate for coastal operations.

Constructed with 20 centimetres of layered armour, Monitor’s rotating turret was the forerunner of the modern naval turret, influencing warship design for the next century. Roughly 20 feet in diameter and nine feet high,

it was powered by two small engines controlling a complex of gears and completed a rotation in just less than 23 seconds.

Monitor was less than 55 metres long, about two-thirds the length of its adversary CSS Virginia. With a beam of roughly 12.5 meters, the ironclad was relatively compact. Its low silhouette presented a minimal target for enemy warships and shore batteries. Well protected at the waterline, Monitor’s armoured belt thickness ranged from 7.6 to 12.7 centimetres, while the iron skin covering its turret was 20cm thick. Its deck armour measured 2.5cm thick, and nearly 23cm of riveted iron plating protected the pilothouse.

LARGE CALIBRE GUNS

John Ericsson originally intended to arm Monitor with two 15-inch Dahlgren smoothbore guns. However, since these were scarce, 11-inch Dahlgrens were mounted instead. Typically, 24 sailors serviced a single gun.

REMOVABLE VENTILATION STACKS

ENGINE COMPARTMENT

RUDDER AND FOUR-BLADE PROPELLER

ROTATING TURRET

In combat, Monitor's rotating turret enabled gunners to train on a moving target without requiring the reorientation of the entire ship, increasing the accuracy and rate of fire of its guns.

REMOVABLE SMOKE STACK

PORTHOLES

A series of glass portholes was incorporated into the deck of Monitor to allow sunlight into the crew compartment. Iron plates covered the portholes when the ironclad went into combat.

LIFEBOATS

PILOTHOUSE

CREW AREA AND MECHANICS

Aside from the turret and pilothouse, Monitor's entire crew compartment, its steam engine and other equipment and machinery were located below the waterline, affording some additional protection against enemy fire.

SPECIFICATIONS

CREW: UP TO 62
COUNTRY OF ORIGIN: USA
COMMISSIONED: 1862
SPEED: 6kts (11km/h)
LENGTH: 179ft (54.6m)
BEAM: 41ft (12.5m)
DISPLACEMENT: 987 TONS
WEAPONS: TWIN 11" SMOOTHBORE DAHLGREN GUNS

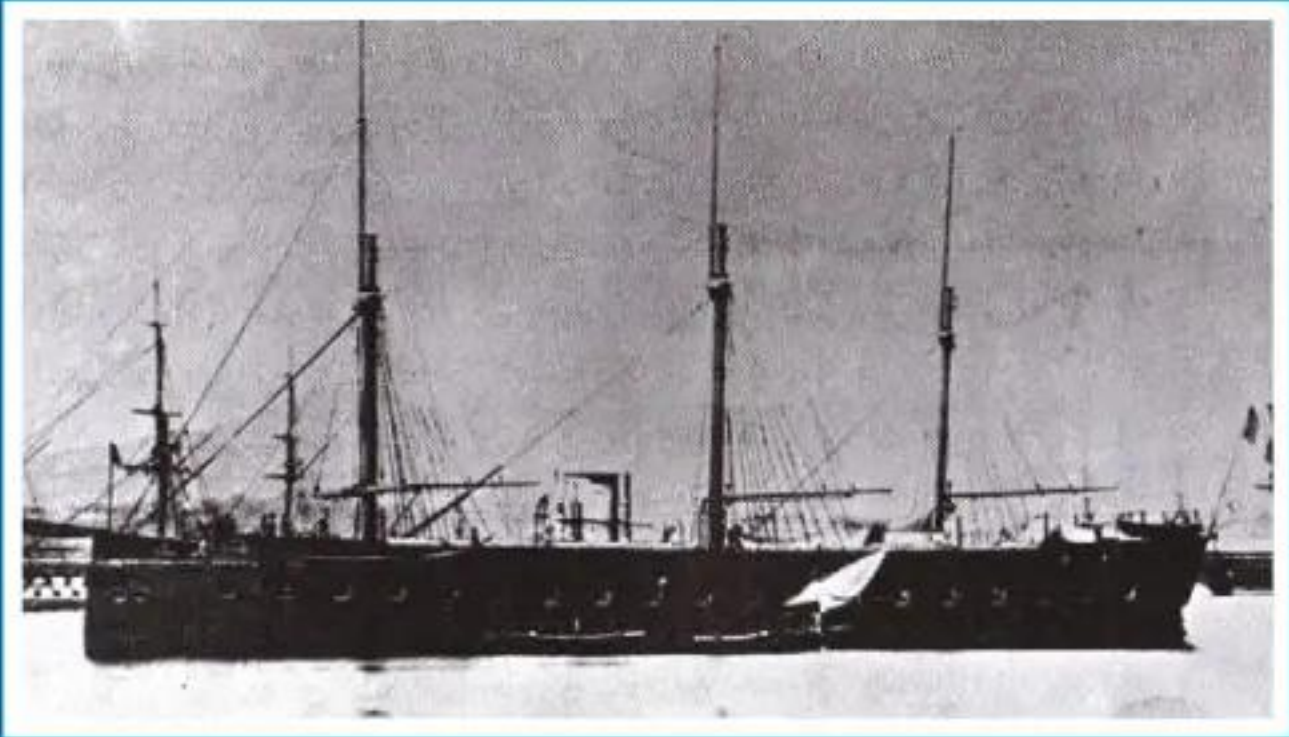
"MONITOR'S ROTATING TURRET WAS THE FORERUNNER OF THE MODERN NAVAL TURRET, INFLUENCING WARSHIP DESIGN FOR THE NEXT CENTURY"

IRON DAWN

Ironclad warships of numerous designs and varied functions began to dominate the world's major naval forces in the mid-19th century

GLOIRE

Displacing 5,529 tons, the French Navy's Gloire was the world's first oceangoing ironclad. Entering service in 1859, Gloire made wooden ships of the line obsolete, only to be eclipsed itself within a year.



HMS WARRIOR

Launched in 1860, HMS Warrior, the Royal Navy's first oceangoing armoured frigate, was constructed with an iron hull. Within a decade, newer designs had begun to relegate Warrior to second-line duties.



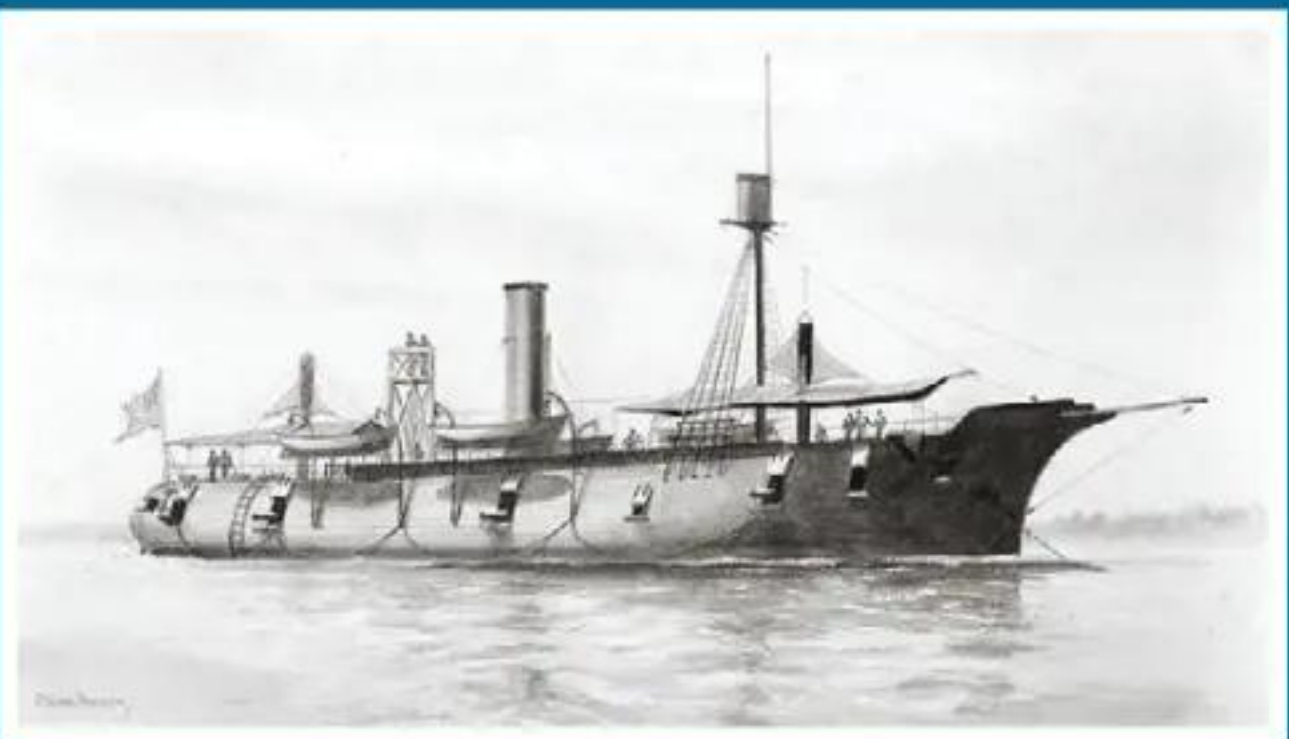
CSS TENNESSEE

The ironclad ram Tennessee was commissioned in February 1864, even as the Civil War was going badly for the Confederacy. Tennessee was captured during the Battle of Mobile Bay.



USS GALENA

Constructed with armour plating covering its wooden hull, the broadside ironclad USS Galena was commissioned in 1862 and sustained serious damage duelling shore batteries during the Battle of Drewry's Bluff.



19th Century

CSS HUNLEY

This innovative Civil War era submarine proved ultimately fatal for its Confederate crew

Constructed by the firm Park and Lyons in Mobile, Alabama, Hunley was the brainchild of Horace L. Hunley, a lawyer, planter and innovator from New Orleans.

Other experiments had been disappointing, but the Hunley design was believed workable, even after two trial deployments ended in tragedies that cost the lives 13 men, including Horace Hunley.

Under control of the Confederate Army, Hunley slipped beneath the harbour waters in Charleston, South Carolina, that fateful night on 17 February 1864 and proceeded towards a cluster of US Navy warships blockading the major Confederate seaport. Under the

command of Lieutenant George E. Dixon, the crew of eight steered toward the 16-gun sloop of war USS Housatonic patrolling 6km off the harbour mouth. The Hunley carried a single torpedo attached to a five-metre spar, and its mission was to shove it into the enemy ship below the waterline, inflicting a mortal wound.

In the murky darkness, Hunley crept closer to Housatonic, finally ramming the torpedo home. The resulting explosion sent Housatonic to the bottom in five minutes. However, Hunley failed to return, its crew slipping to a watery grave – probably due to the same explosion that doomed Housatonic. In 2017 researchers speculated that Hunley's crew were killed or incapacitated by the shockwave from the blast.

INTERNAL BALLAST TANKS

Hunley was fitted with ballast tanks both at the bow and the stern to provide additional weight for submersion and to assist the submarine in remaining on an even keel. These tanks could be flooded by manually opening valves and were pumped dry by hand to lighten the submarine, which weighed seven and a half short tons.

VENTILATION

A pair of snorkels were attached to Hunley's hull just abaft of the forward conning tower. These could be raised and lowered as needed. Along with an accompanying bellows system installed just behind the commander's position, the snorkels were used to pump fresh air into the crew compartment, which otherwise would run out of oxygen within a short time as heat or cold became debilitating.

SPAR AND TORPEDO

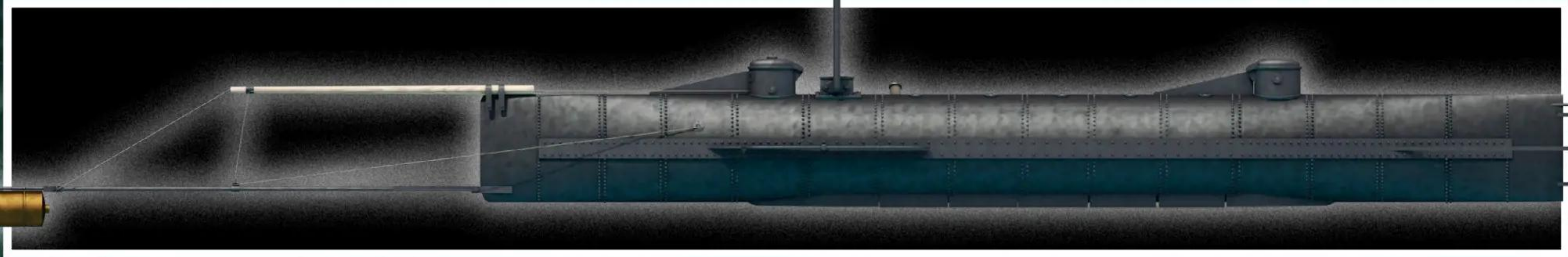
Hunley's five-metre spar was tipped with a torpedo filled with black powder, expected to produce a catastrophic explosion after being rammed into the hull of a Union warship below the waterline. The weapon worked during the attack on the US Navy sloop of war Housatonic, but Hunley did not survive its only combat mission, probably disabled by the same explosion that sank Housatonic on the night of 17 February 1864.

SPECIFICATIONS

CREW: 8
COUNTRY OF ORIGIN: CONFEDERATE STATES
COMMISSIONED: 1863 (UNOFFICIALLY)
SPEED: 4kts (7.5km/h)
LENGTH: 36ft (11m)
POWERPLANT: 8-MAN HAND-CRANKED
SCREW PROPELLAR
WEAPON: 40lb SPAR-MOUNTED MINE

COMMANDER'S POSITION

Lieutenant George E. Dixon took the Hunley helm forward of the lead conning tower, where the steering controls were located. Dixon, originally an infantry officer, had been wounded at Shiloh in April 1862, a Union bullet glancing off a \$20 gold piece in his pocket, likely saving his life. Dixon had the coin inscribed and kept it as a good luck piece. In 2002, it was found between clothing folds as his remains were examined.



CONNING TOWERS, HATCHES

Hunley was constructed with a pair of small but prominent conning towers located fore and aft that offered limited visibility when the submarine was underway. The conning towers were also equipped with hatches for crew ingress and egress. Although the hatches were quite narrow, measuring only 1.4ft (42cm) wide and 1.7ft (53cm) long, researchers were surprised to discover that they were somewhat larger than had been originally believed.

DEAD LIGHTS

Once the crew of eight men had occupied Hunley, the interior of the submarine was cramped and dark. A series of 'dead lights' was installed atop the spine of the submarine to provide as much ambient light as possible, facilitating the work of the crew with wrenches and other tools that were used to make Hunley watertight and allow entry and exit.

PROPELLER AND RUDDER

The hand-cranked propeller of Hunley turned at the speed generated by the crew's exertion, and operating the crank was backbreaking work. The propeller was protected by an external iron ring and was offset to the starboard side of the submarine. The rudder was located at the rear of the submarine and answered the helm, steering Hunley through the murky waters of Charleston harbour during its fateful mission.

EXTERNAL DIVE PLANES

External dive planes, shaped like wings, were attached to the starboard and port sides of Hunley's hull. These were manipulated by the commander, angling them upward or downward to control the depth of the submarine while underway. During an exploratory dive in 1995, a portion of Hunley was cleared of silt, exposing the dive plane on the port side of the submarine and yielding a preliminary measurement of Hunley's length at 36 foot (11 metres).

CREW COMPARTMENT

The eight members of the Hunley crew consisted of the commander, first officer, and six enlisted men. The crew compartment included a bench to accommodate seven men as they turned a hand crank to provide propulsion for the submarine. The first officer's position was in the stern, adjacent to the aft conning tower. From there, he was able to assist with the propulsion of the submarine, which was capable of moving through the water at a speed of approximately four knots.



Illustration: Adrian Mann

First World War

HMS DREADNOUGHT

The dominant battleship of its era, this new vessel revived the naval arms race that intensified Anglo-German tensions in the lead up to World War I

As the figurehead of the Royal Navy, HMS Dreadnought kick-started a new era of ship development. Although it wasn't the first 'big-gun' ship in production – that honour is bestowed on Imperial Japan, who unsuccessfully attempted to build the IJN Satsuma in 1904 – its design sent shock waves across the naval world. Built in direct response to German efforts to challenge British supremacy on the sea, HMS Dreadnought was the first truly modern warship, combining a revolutionary armament supply, an electronic rangefinding weapons system and advanced speed technology. Its iconic status is secured despite never sinking another battleship.

MODERN OPTICAL RANGEFINDERS

HMS Dreadnought was the most accurate battleship of its time in determining distance. It was fitted with an electrical rangefinder developed exclusively by Barr and Stroud, two physics and engineering professors at the Yorkshire College (now the University of Leeds).

12-POUNDER GUNS

Dreadnought's 12-pounder guns acted as a form of defence against torpedo boats. Placed either at the top of the turrets or on the side of the ship, these 76mm guns had a range of 5.3 miles.

DUMARESQU MECHANICAL COMPUTER

TRANSMITTING STATION

A new Vickers Range Clock was used on board HMS Dreadnought for continuously calculating the changing range between the target vessel and an enemy ship. Corrections could be made to update the clock at any time, so the ship was always one step ahead.

STRATEGIC MAN POWER

Reversing a trend set in stone for centuries, HMS Dreadnought housed its officers and enlisted men forward, much closer to the bridge, in an effort to ensure that everybody on board was as close to their action stations as possible.

KRUPP CEMENTED ARMOUR

Krupp armour, which carbonised steel for greater hardness, was replaced at the turn of the 20th century by Krupp cemented armour and used to make Dreadnought. Its revolutionary composition promoted greater elasticity, reducing the chances of cracking.

REDUCED WATERLINE BELT

QUICKER THAN THE REST

HMS Dreadnought was the first ship to use an experimental steam turbine engine rather than the triple-expansion engine. At the time, it was the quickest ship ever, reaching a speed of 21 knots (39 kilometres per hour) despite its extra, weighty firepower.

“HMS DREADNOUGHT WAS THE FIRST TRULY MODERN WARSHIP, COMBINING A REVOLUTIONARY ARMAMENT SUPPLY, AN ELECTRONIC RANGEFINDING WEAPONS SYSTEM AND ADVANCED SPEED TECHNOLOGY”

ATTACKING FIREPOWER

Dreadnought was the world's most feared battleship because of its astonishing firepower. It was built to shine in combat situations thanks to its five 12-inch twin-gun turrets that had a range of up to 14.2 miles.

THREE CENTRAL TURRETS FOR WEIGHT STABILIZATION

TORPEDO CONTROL TOWER

SUPERIOR FIRE CONTROL

All 12-inch guns on board had identical ballistic characteristics, which simplified the task of adjusting fire in battle. This was previously not possible because guns of a different calibre created different splashes and observers would not be able to guide effectively.

23,000 SHAFT HORSE POWER

FIRE DOORS

A major improvement on what came before it, HMS Dreadnought removed longitudinal passageways between compartments below deck. Taking cues from submarines, the ship's connecting doors were to be kept shut to prevent the spread of fire and flooding.

FUEL SUPPLY

At full capacity, Dreadnought could steam for 6,620 nautical miles (12,260 kilometres) at ten knots (19 kilometres per hour). It carried 2,914 tons of coal and 1,140 tons of fuel oil that was sprayed on to increase its burn rate.

SPECIFICATIONS

CREW: 773
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1906
RANGE: 6,620 MILES (12,260km)
SPEED: 21kts (39km/h)
LENGTH: 527ft (160.6m)
BEAM: 82ft (25m)
DISPLACEMENT: 18,420 TONS
POWERPLANT: 2x PAIRED SETS OF PARSONS DIRECT-DRIVE STEAM TURBINES
WEAPONS: 5x 12" (305mm) TWIN-GUN TURRETS; 18x QF 12-POUNDER GUNS

BATTLE OF JUTLAND

31 MAY
1916

After years of building up battleships to dominate the oceans, the British and German navies finally came to blows in the North Sea

In early 1916, the North Sea was far from the battleground it would become, as the Royal Navy continued its blockade of the Imperial German Navy. Admiral Reinhardt von Scheer's appointment that year changed things as he ordered his ships to break out against the British barricade. Across the water, the British had grown tired of months spent skirmishing with German vessels, and were already mobilising in response. The Royal Navy's Grand Fleet would finally face off against the German High Seas Fleet, as the results of the long arms race finally came to fruition.

“THE BRITISH HAD GROWN TIRED OF MONTHS SPENT SKIRMISHING WITH GERMAN VESSELS, AND WERE ALREADY MOBILISING IN RESPONSE”

THE NAVIES OF JUTLAND		
THE STRENGTH OF THE TWO NAVIES AT WWI'S DEFINING SEA CONFLICT		
	BRITISH GRAND FLEET	GERMAN HIGH SEAS FLEET
DREADNOUGHTS	28	16
PRE-DREADNOUGHTS	0	6
BATTLE CRUISERS	9	5
LIGHT CRUISERS	26	11
DESTROYERS	77	61
ARMOURED CRUISERS	8	0
SEAPLANE CARRIERS	1	0
MINELAYERS	1	0



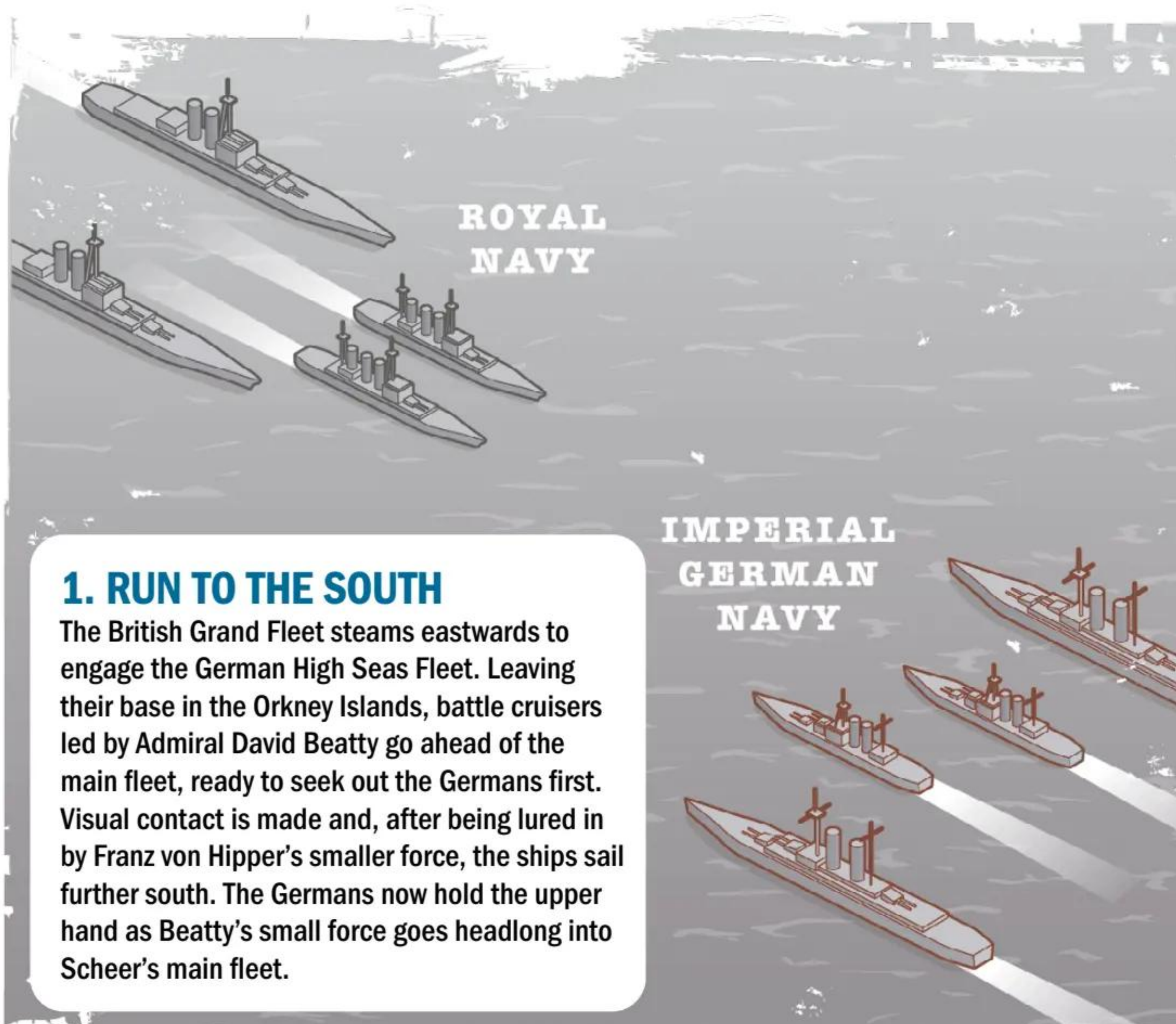
While no dreadnoughts were lost, three British battle cruisers and eight destroyers were sunk by the Germans at Jutland

JUTLAND: THE AFTERMATH

HOW THE END OF THE ARMS RACE PRODUCED BITTERSWEET VICTORY

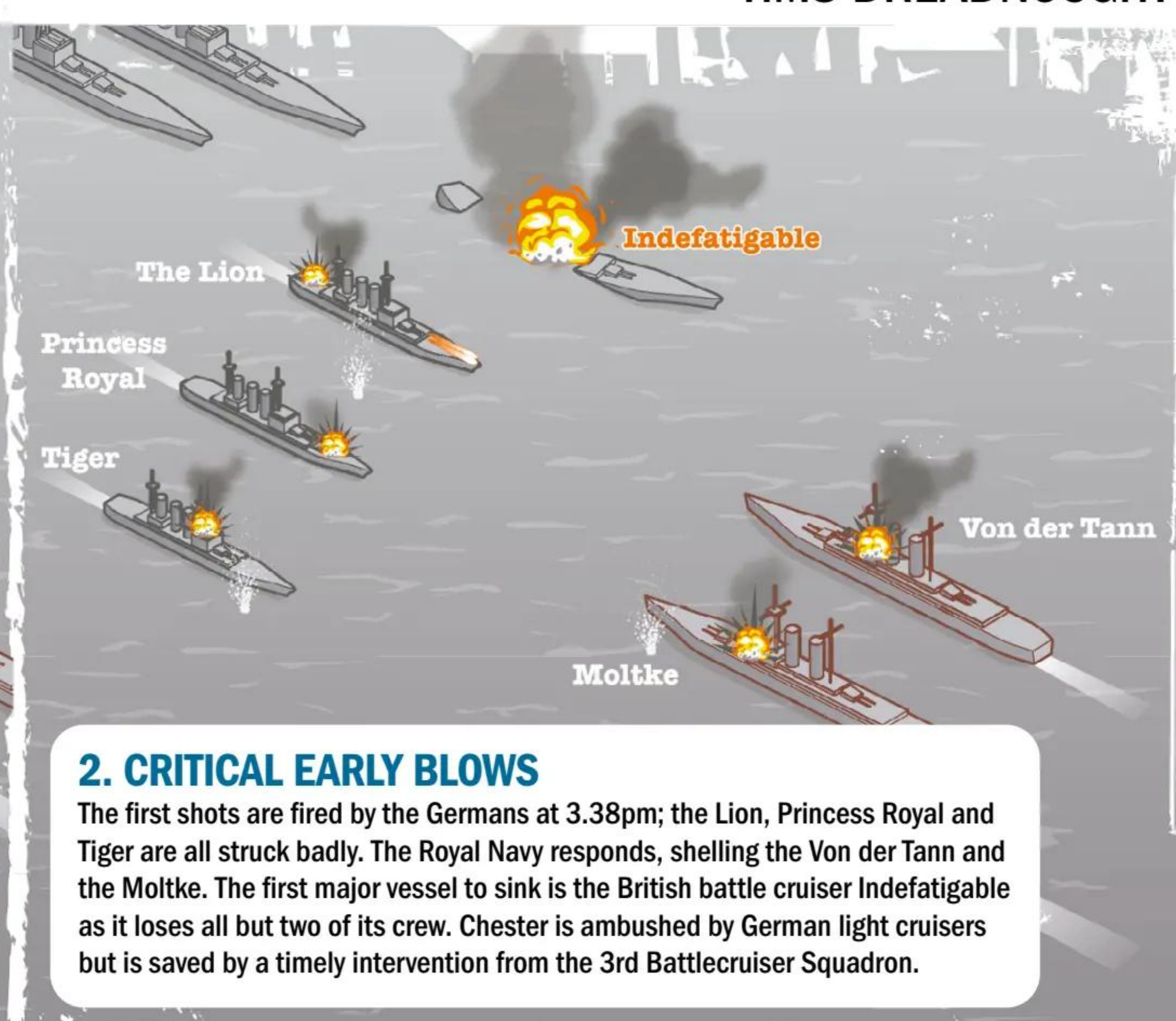
For two very proud nations, the loss of ships was hard to take. Although no dreadnoughts were sunk, many destroyers and battle cruisers were lost by both navies, with Britain recording more casualties. Despite losing more vessels and manpower, the German retreat meant the Royal Navy now had undisputed control of the North Sea, but the lack of a stunning victory was not lost on the British public, who were expecting a success of Trafalgar proportions. The inconclusive result of the battle was disappointing to the military hierarchy as well, as it was hoped that these metal leviathans could turn the tide of the war.

Admiral Jellicoe was criticised by Churchill for not taking a riskier approach and it is true that if he hadn't feared a torpedo attack to such an extent, he could have knocked the German Navy out of the war at Jutland. However, this takes away from the key manoeuvres and tactics that Jellicoe exercised prior to this moment. So soon after one of the largest arms races of all time, the role of battleships had changed and the age of the submarines and aircraft carriers was about to begin.



1. RUN TO THE SOUTH

The British Grand Fleet steams eastwards to engage the German High Seas Fleet. Leaving their base in the Orkney Islands, battle cruisers led by Admiral David Beatty go ahead of the main fleet, ready to seek out the Germans first. Visual contact is made and, after being lured in by Franz von Hipper's smaller force, the ships sail further south. The Germans now hold the upper hand as Beatty's small force goes headlong into Scheer's main fleet.



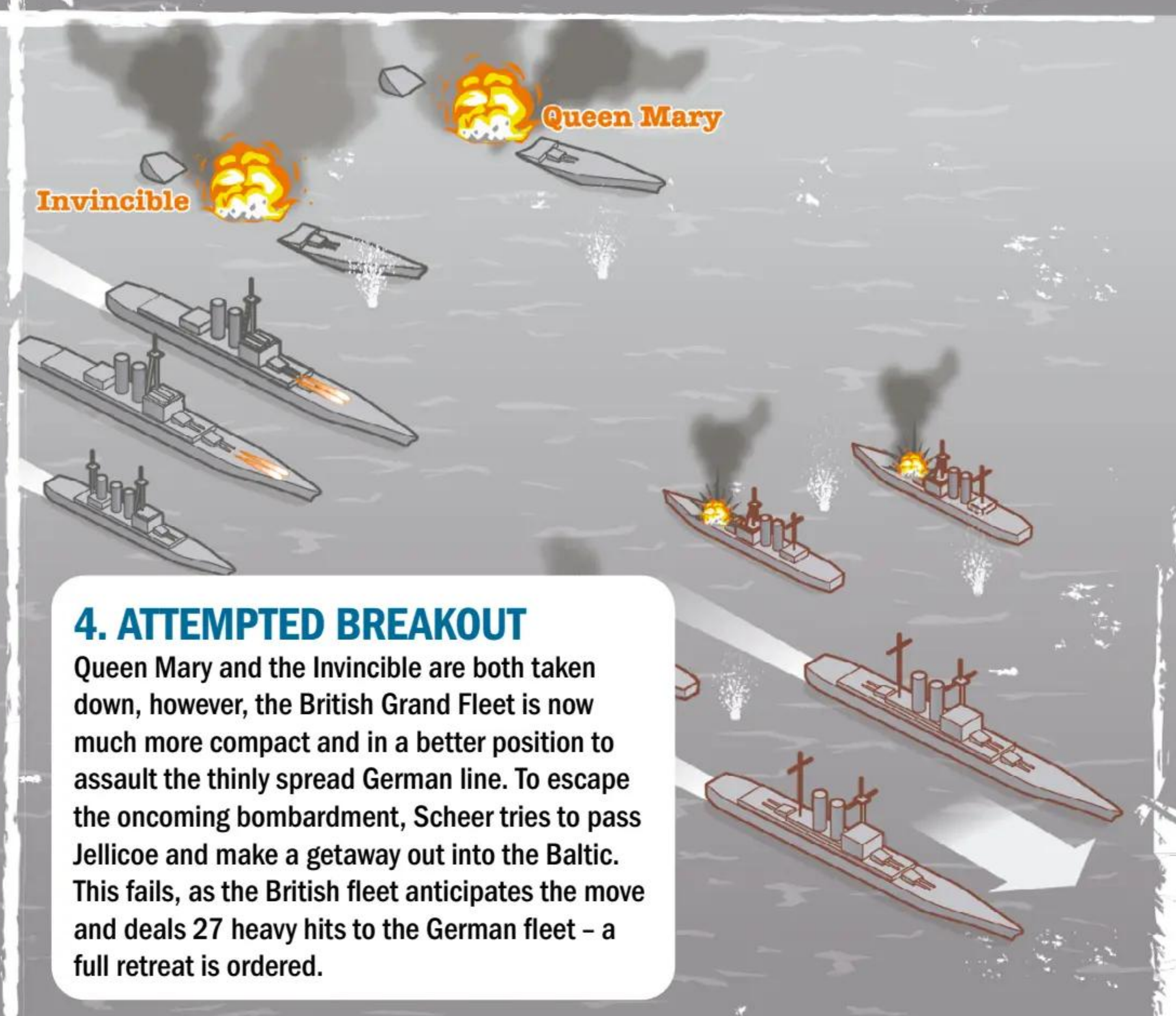
2. CRITICAL EARLY BLOWS

The first shots are fired by the Germans at 3.38pm; the Lion, Princess Royal and Tiger are all struck badly. The Royal Navy responds, shelling the Von der Tann and the Moltke. The first major vessel to sink is the British battle cruiser Indefatigable as it loses all but two of its crew. Chester is ambushed by German light cruisers but is saved by a timely intervention from the 3rd Battlecruiser Squadron.



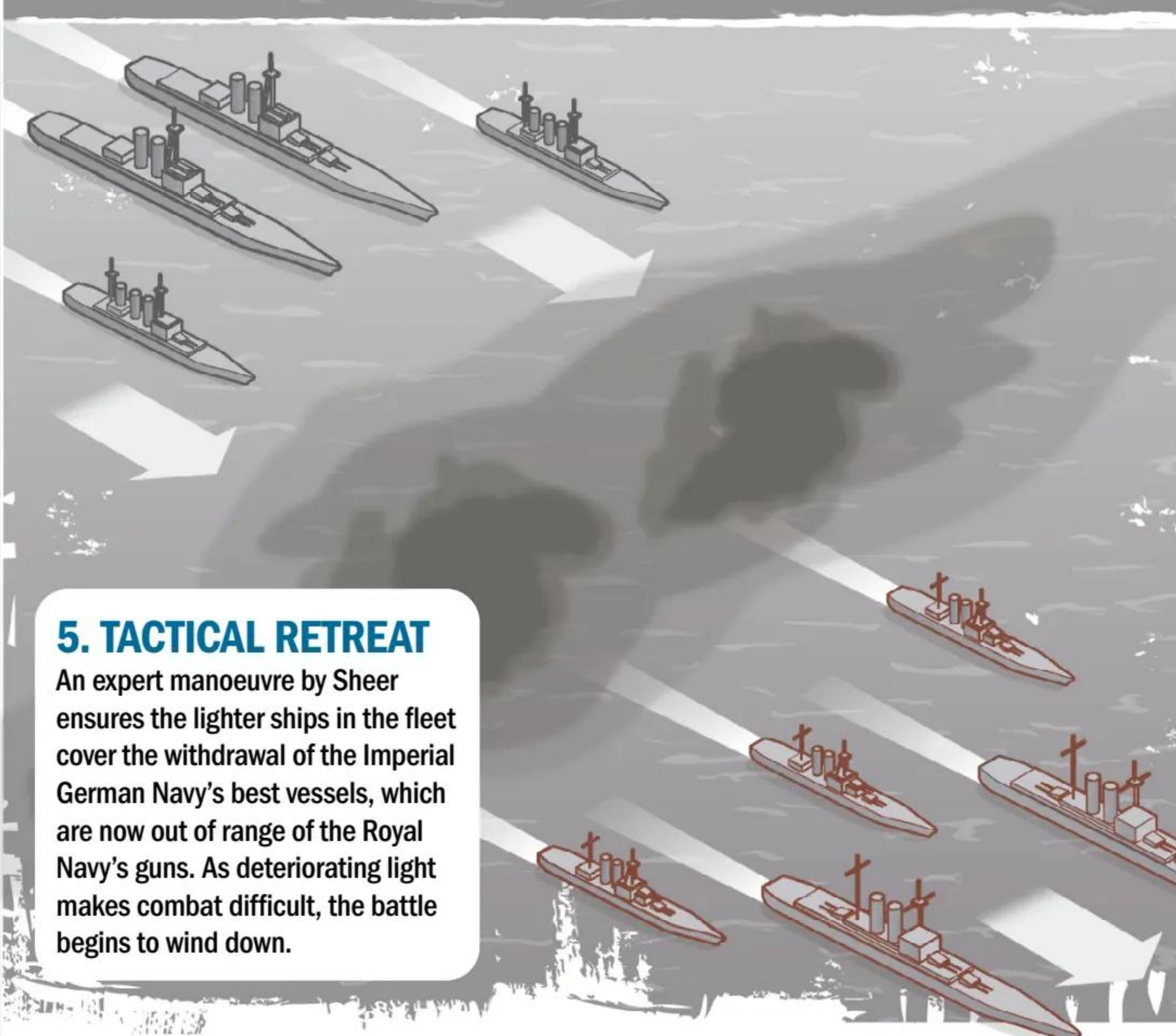
3. RUN TO THE NORTH

Beatty turns back to join up with the main British force that looms into view through the haze. Hipper orders his fleet to sail north as Admiral John Jellicoe's main battle fleet enters the fray. Jellicoe heads south, cutting the Germans off before they are aware of the British trap. As the fleets clash, the Lutzow is sunk and the Seydlitz and Derfflinger are badly damaged as the loss of the Indefatigable is avenged.



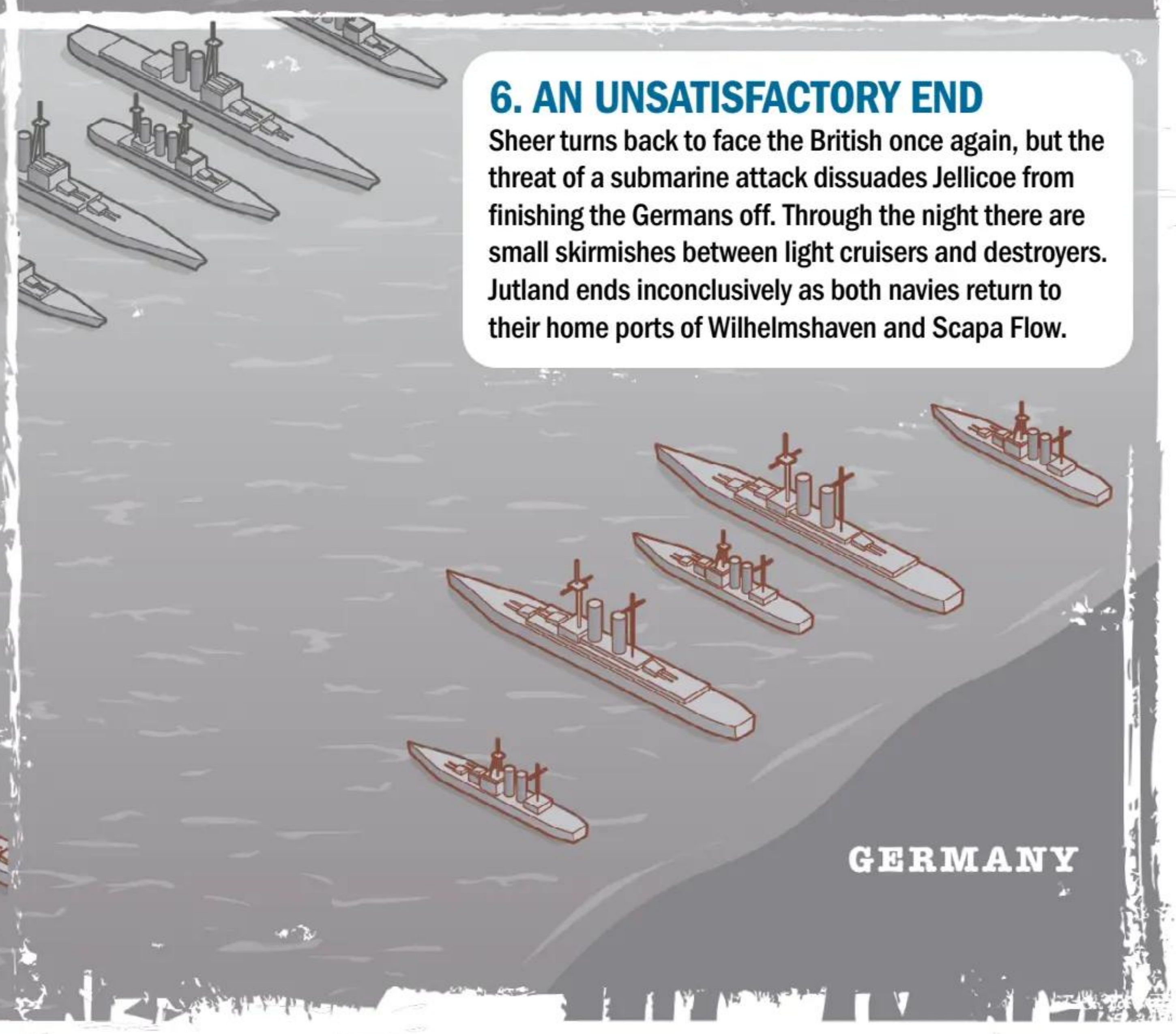
4. ATTEMPTED BREAKOUT

Queen Mary and the Invincible are both taken down, however, the British Grand Fleet is now much more compact and in a better position to assault the thinly spread German line. To escape the oncoming bombardment, Scheer tries to pass Jellicoe and make a getaway out into the Baltic. This fails, as the British fleet anticipates the move and deals 27 heavy hits to the German fleet – a full retreat is ordered.



5. TACTICAL RETREAT

An expert manoeuvre by Sheer ensures the lighter ships in the fleet cover the withdrawal of the Imperial German Navy's best vessels, which are now out of range of the Royal Navy's guns. As deteriorating light makes combat difficult, the battle begins to wind down.



6. AN UNSATISFACTORY END

Sheer turns back to face the British once again, but the threat of a submarine attack dissuades Jellicoe from finishing the Germans off. Through the night there are small skirmishes between light cruisers and destroyers. Jutland ends inconclusively as both navies return to their home ports of Wilhelmshaven and Scapa Flow.

SUPERMARINE S.6B

The world's fastest machine in its time, the S.6b laid some of the groundwork for the later Spitfire

Designed by a team led by the legendary Reginald J. Mitchell, the Supermarine S.6b float plane was built with a single purpose in mind – speed.

It was a development of the S.6, winner of the 1929 Schneider Trophy, an international maritime air race. The S.6b was to enter the 1931 competition. After victories at the previous two races, if the British team (under the auspices of the RAF High Speed Flight) could win for a third time they would get to keep the trophy and the competitions would come to an end.

The S.6b was built with an improved Rolls Royce R engine and numerous modifications to the airframe. It pushed the boundaries of technology in many ways, from aerodynamics to construction techniques, while the engine also broke new ground. R. J. Mitchell would estimate that the pressure of the competition pushed forward development at three times the normal peacetime rate, and certainly allowed him to hone the skills and knowledge that he would later pour into his masterpiece, the Supermarine Spitfire.

Not only did the S.6b permanently win the Schneider Trophy for Britain, it would set, break and re-set the World Speed Record in its short but spectacular life.

“NOT ONLY DID THE S.6B PERMANENTLY WIN THE SCHNEIDER TROPHY FOR BRITAIN, IT WOULD SET, BREAK AND RE-SET THE WORLD SPEED RECORD”

LIGHTWEIGHT AND STRONG

The S.6b was an all-metal cantilever monoplane with a semi-monocoque fuselage. The skin helped take the stresses, saving weight on the internal structure.

A NECESSARY DRAG

The Schneider was a race for seaplanes, and the floats were a major limit on the designs. However, the S.6b found ways to make the floats work.

COCKPIT

The cockpit of the S.6b was sparse and functional. Pilot protection in the open cockpit was minimal, with just an inadequate windshield in front. Spray easily coated the pilot's goggles, further compounding what was already a poor view. The controls were simple, with rudders in the usual places, a simple stick for steering, and throttle controls on the left side wall of the cockpit. Instruments were also basic, with very little needed for an aircraft only intended for short range and limited duration flights.

HIGH SPEED CONTROLS

As well as construction techniques and aerodynamics, the S.6b forged new ground in how control surfaces were designed to cope with higher speeds.

ENGINE

The Rolls Royce R 12 cylinder, supercharged, water-cooled engine was a ground breaking piece of machinery. Based on the Rolls Royce Buzzard, design started in November 1928, specifically aimed at powering the Supermarine S.6 in the September 1929 Schneider Trophy. After helping the S.6 achieve a new world air speed record at 355.8mph (572.6kmh), development continued. It pushed the boundaries in terms of materials, super-charging, and cooling as well as fuel types. The 1931 version could reach powers of 1700Kw (2,300hp), and again set new records. After the Schneider Trophy, modified versions of the R were also used in world land and sea speed record attempts, while much of the science and engineering learned was poured into a new aero engine, the Rolls Royce Merlin.

RADIATOR WINGS

Water from the engine cooling system was routed through pipes in the wings. Vents allowed air to blow through the structure to speed the cooling process.

SPECIFICATIONS

CREW: 1
COUNTRY OF ORIGIN: UK
COMMISSIONED: 1931
RANGE: N/A
TOP SPEED: 407.5mph (655km/h)
ENGINE: ROLLS ROYCE R, 12-CYLINDER
SUPERCHARGED 36.7l
WEAPON: NONE

Second World War

IJN AKAGI

The first fleet aircraft carrier of the Imperial Japanese Navy, Akagi was sunk at the Battle of Midway in 1942

Commissioned on 25 March, 1927, Akagi played a significant role in the development of Japanese carrier aviation doctrine and the implementation of the carrier strike group and its operational First Air Fleet, or Kido Butai. The carrier commenced combat operations off the coast of China during the Second Sino-Japanese War in 1939-1940.

Akagi became the flagship of the Kido Butai that struck the U.S. Pacific Fleet at Pearl Harbor and other installations on the Hawaiian island of Oahu on 7 December, 1941. Afterward, Akagi supported the invasion of New Britain followed by extensive carrier-based air operations, including the devastating raid on Darwin, Australia, in February 1942. From there, Akagi launched aircraft frequently during operations in the

Indian Ocean, eventually compelling the British Royal Navy to retire westward.

In June 1942, Akagi spearheaded the Japanese naval armada intent on destroying the U.S. Navy's carriers and occupying strategically vital Midway Atoll 1,300 nautical miles west of Oahu. In a dramatic shift of the balance of power in the Pacific, Akagi was scuttled during the Battle of Midway after American dive bombers struck the carrier and ignited fires that were soon out of control. Three other carriers, Kaga, Soryu, and Hiryu, were also destroyed.

Akagi sank in the predawn hours of 5 June, 1942, with the loss of 267 crewmen. The wreck was discovered by the research vessel RV Petrel in October 2019 resting upright on the sea floor at a depth of more than 18,000 feet (5,486 metres).

FLIGHT DECK

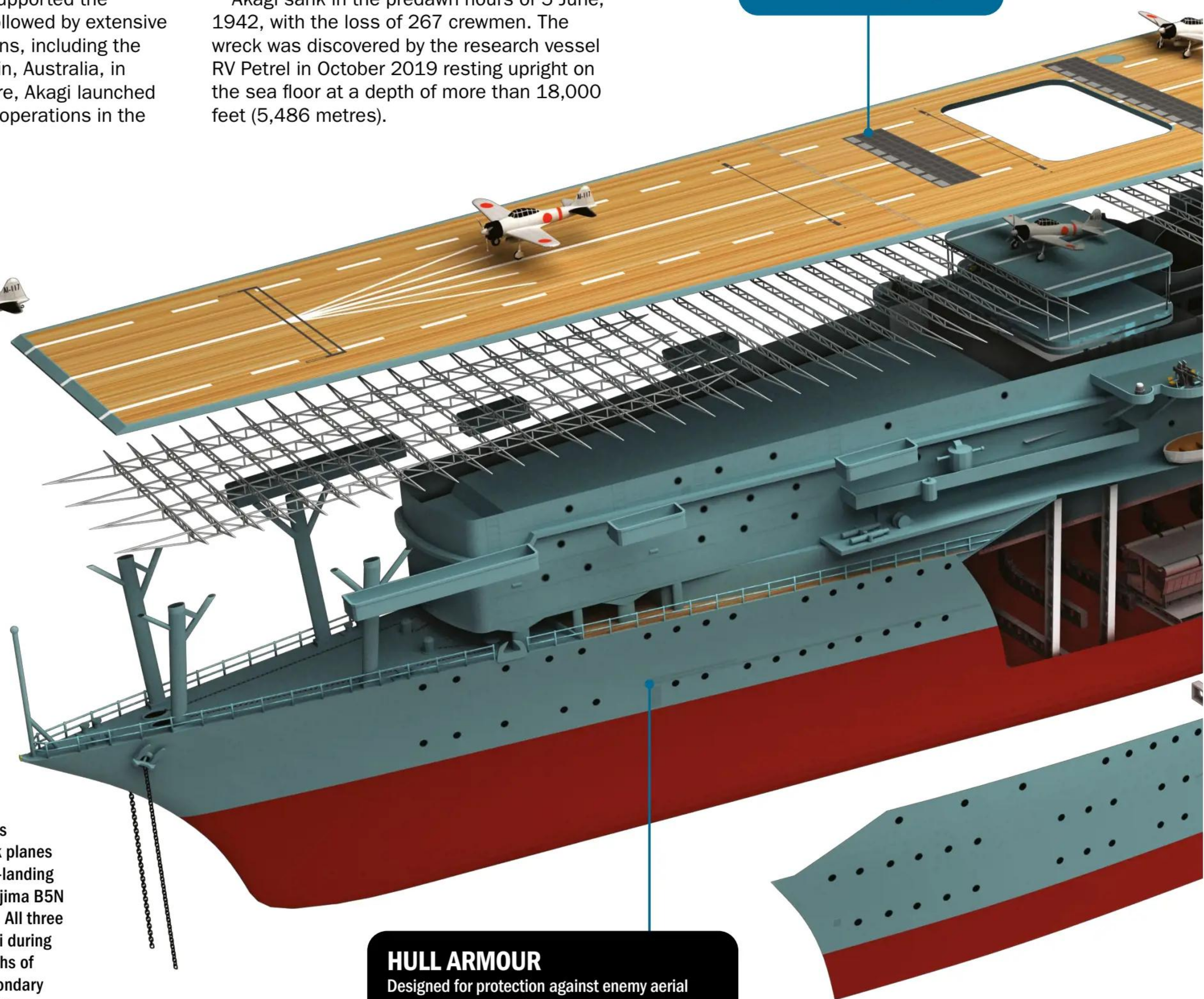
Originally built with three flight decks, after an extensive rebuild the remaining Akagi platform stretched 819 feet. Air operations relied on highly trained crews that moved planes on and off the deck rapidly.

ARMAMENT

The primary weapons aboard the Imperial Japanese Navy aircraft carrier Akagi were its complement of naval combat aircraft. These included the legendary Mitsubishi A6M Zero fighter, utilized in combat air patrol and security as well as escort service with other attack planes such as the Aichi D3A Val fixed-landing gear dive bomber and the Nakajima B5N Kate torpedo and level bomber. All three types were in service with Akagi during operations in the opening months of World War II in the Pacific. Secondary armament consisted primarily of anti-aircraft defence weapons, including 25mm and 127mm guns, along with 200mm guns as well.

HULL ARMOUR

Designed for protection against enemy aerial ordnance and torpedoes, the armour protection of Akagi was more than six inches thick at the belt and three inches on the flight deck.



POWERPLANT

The powerplant of the aircraft carrier Akagi consisted of four Gijutsu-Hombu steam turbines fed from 19 Kampon boilers and generating 133,000 shaft horsepower delivering a top speed of 31.5 knots. The turbines were commonly employed in capital ships of the Imperial Japanese Navy and were engineered during the interwar years for production in the home islands to eliminate dependence on foreign technology. The standard Kampon boiler was adopted in 1914 and lined with brick to prevent the escape of excessive heat. Each water tube boiler was capable of producing steam pressure at 427 pounds per square inch with temperatures of 662 degrees Fahrenheit.

ISLAND

Akagi was originally constructed without an island. However, one was built on the port side of the carrier to facilitate command and control during a long refit that took place from 1935 to 1938.

Japanese aircraft carrier "Akagi", in the Sukumo Bay; April 1939



ELEVATORS

After the refit of the late 1930s, a third elevator became operational aboard Akagi, allowing easier movement of aircraft from the hangar deck below during launch execution and shuttling aircraft below after recovery.

CREW SPACES

Crew spaces aboard Akagi were cramped and far from accommodating. They were austere and lacked comforts such as air conditioning, while enlisted personnel were assigned multi-level compartments with virtually no space for personal belongings except a small locker. The atmosphere in the compartments below deck was often oppressively hot and humid during operations in tropical climates. The funnel system ran along the hull, sometimes adding to the heat and introducing noxious exhaust fumes to the living area. Senior officers were accommodated in staterooms that were somewhat larger with a few amenities while pilots were berthed directly in ready rooms or small cabins to ensure quick access to aircraft.

"AKAGI SANK IN THE PREDAWN HOURS OF 5 JUNE, 1942, WITH THE LOSS OF 267 CREWMEN"

SPECIFICATIONS

CREW: 2,000
COUNTRY OF ORIGIN: IMPERIAL JAPAN
COMMISSIONED: 1927
RANGE: 12,000 MILES (22,224km)
SPEED: 31.5kts (58km/h)
LENGTH: 85ft (26m)
BEAM: 101ft (31m)
DISPLACEMENT: 27,300 TONS
POWERPLANT: 4x GIJUTSU-HOMBU
 STEAM TURBINES; 19x KAMPON BOILERS
WEAPONS: 8x TWIN 127mm AA & 14x
 TWIN 25mm AA GUNS; 6x 200mm GUNS

U-48 TYPE VII-B

The German submarine U-48 was the most successful weapon of its type deployed during World War II

The Type VII-B U-48 was laid down in March 1937 at the Germaniawerft yards at Kiel, Germany, and commissioned on 22 April 1939. During its 22-month wartime career the U-48 sank or damaged 55 ships totalling 328,414 tons, a record unsurpassed in World War II.

The U-48 operated in two wolfpacks during the early months of the war and survived serious damage in numerous encounters with

Allied convoy escort vessels. It spent 325 days at sea and completed its war patrols under three commanders – Kapitänleutnant Herbert Schultze, Korvettenkapitan Hans Rudolf Rösing, and Kapitänleutnant Heinrich Bleichrodt. Each commander received the Knight's Cross, as did officers Reinhard Suhren and Erich Zürn.

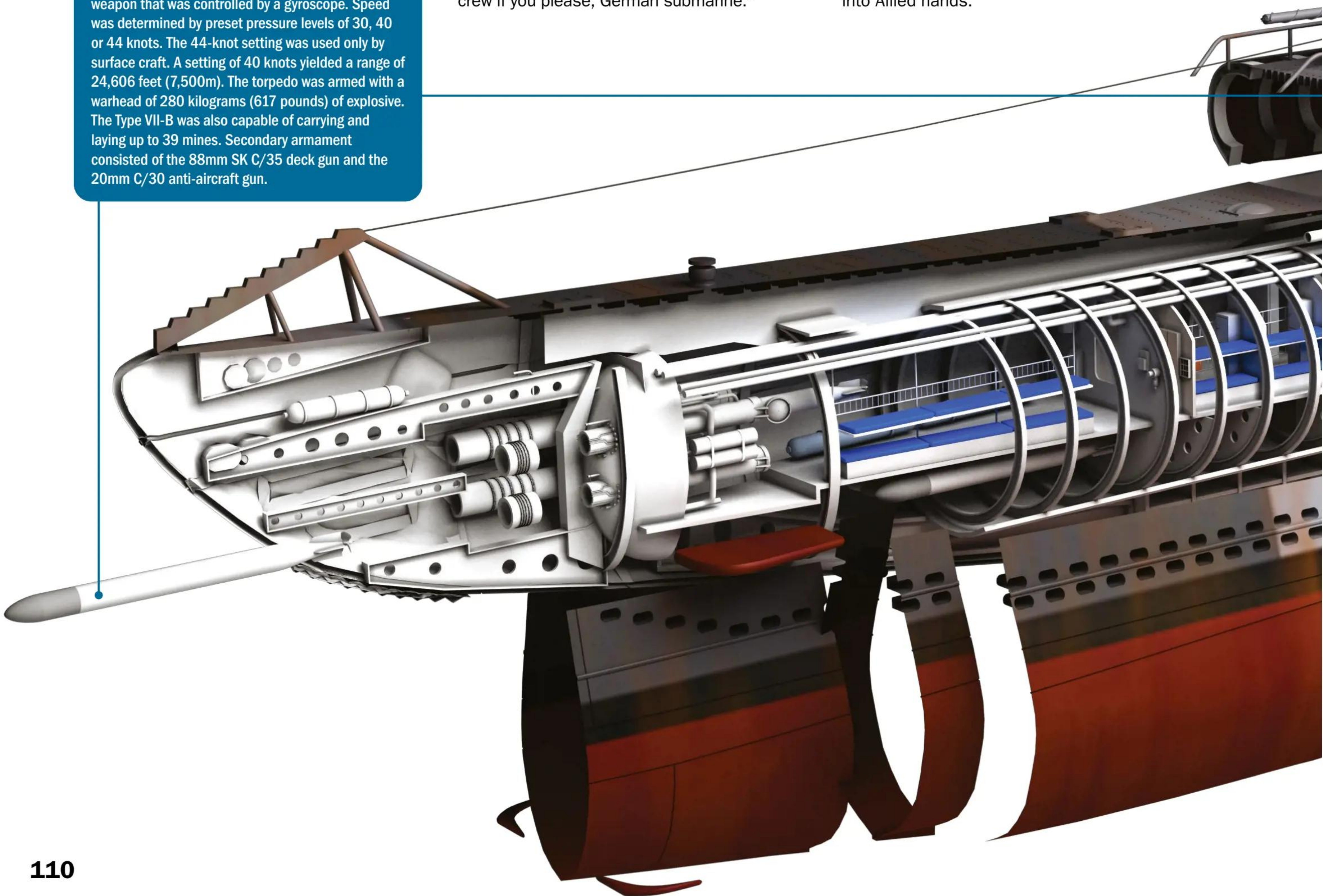
The U-48 achieved its first kill on 5 September 1939, just two days after Britain and France declared war on Germany, sinking the 4,853-ton merchant vessel *Royal Sceptre* with its 88mm deck gun. After sinking the 5,055-ton *Winkleigh* on 8 September, U-48 dispatched the 4,869-ton *Firby* three days later and radioed the message, "Transmit to Mr Churchill. I have sunk the British steamer *Firby*. Posit 59°40'N 13°50'W. Save the crew if you please, German submarine."

During its seventh war patrol U-48 sank the 1,060-ton sloop of war *HMS Dundee* on 15 September 1940, which was followed on the 18 September with a tragic event of World War II. With Bleichrodt in command, the U-48 torpedoed the steamer *SS City of Benares*, which was participating in a programme to evacuate British children to Canada. 90 children were aboard the ship and 77 died. A total of 258 crew and passengers perished.

The U-48 concluded its last patrol on 21 June 1941 and returned to Kiel. It was subsequently transferred to the 26th Bootflotille at Pillau and then to the Third U-boat Lehr Division to be used as a training craft. The boat was scuttled by its crew on 3 May 1945 to prevent it falling into Allied hands.

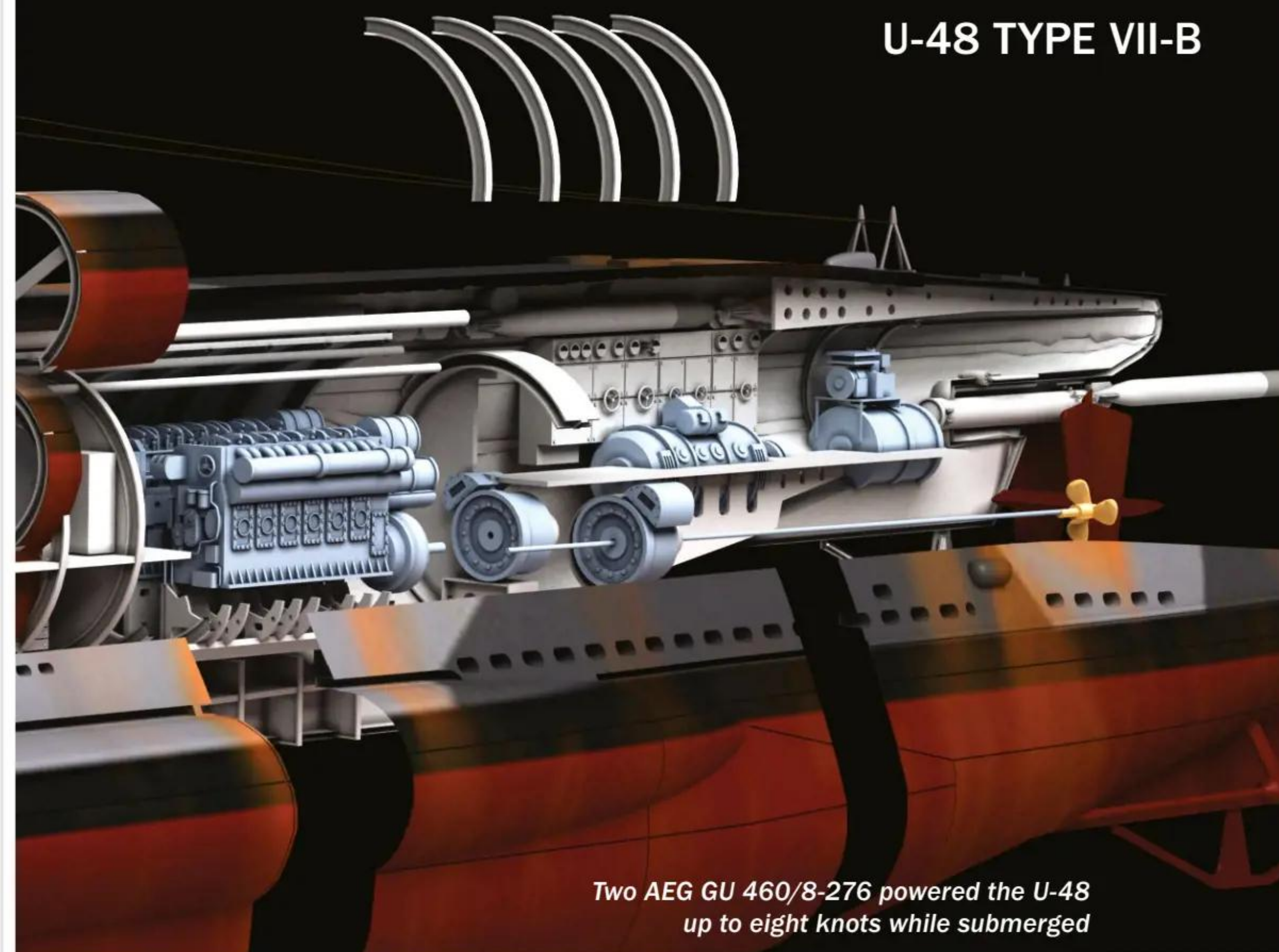
ARMAMENT

Early in World War II the standard German torpedo was the G7a(TI), a variable-speed, steam-powered weapon that was controlled by a gyroscope. Speed was determined by preset pressure levels of 30, 40 or 44 knots. The 44-knot setting was used only by surface craft. A setting of 40 knots yielded a range of 24,606 feet (7,500m). The torpedo was armed with a warhead of 280 kilograms (617 pounds) of explosive. The Type VII-B was also capable of carrying and laying up to 39 mines. Secondary armament consisted of the 88mm SK C/35 deck gun and the 20mm C/30 anti-aircraft gun.



DESIGN

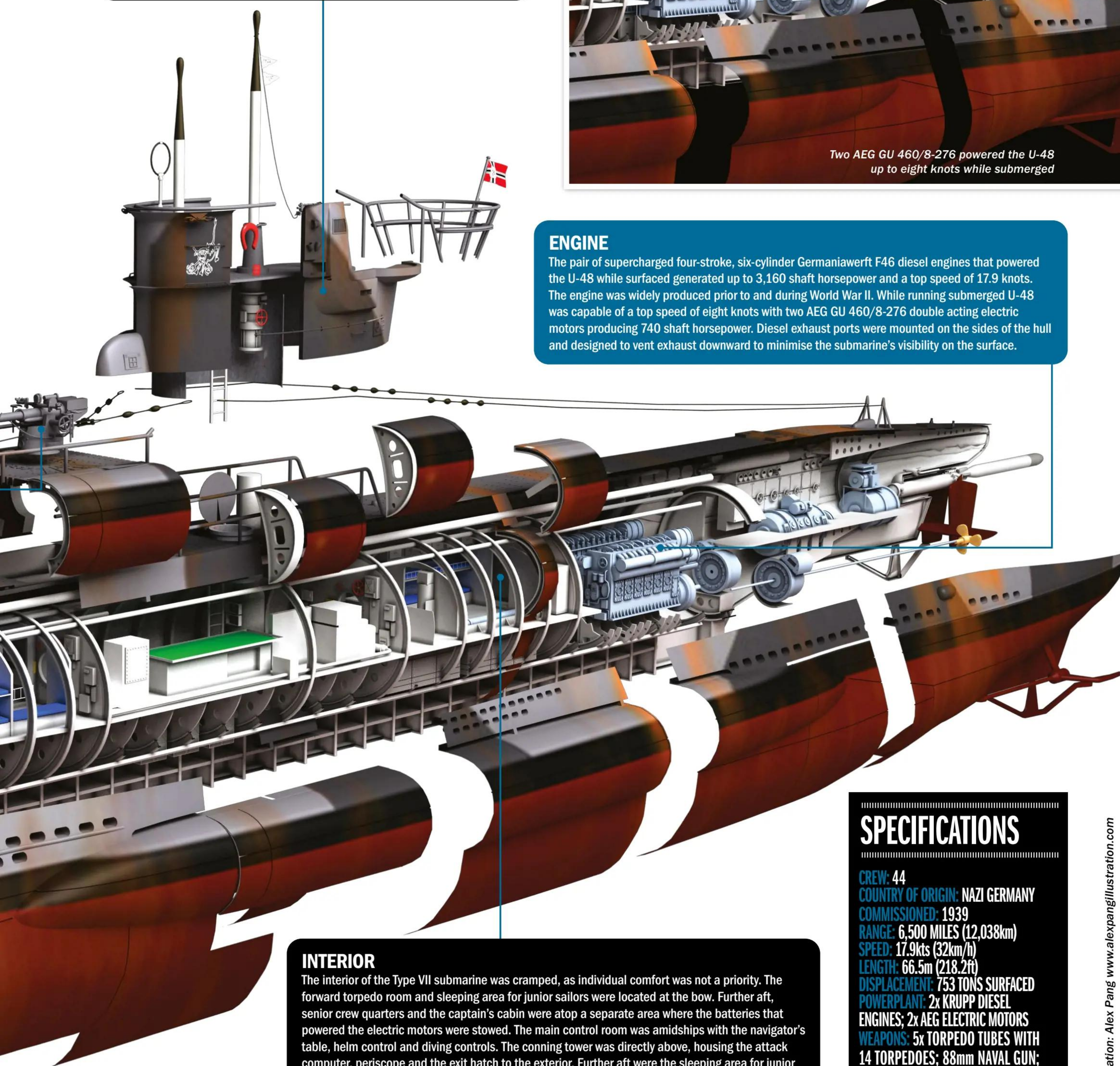
The Type VII-B's design was a substantial improvement over its predecessor, the Type VII-A. In the U-48 and its sister U-boats the aft torpedo tube, previously located outside the pressure hull, was brought inside. The hull was lengthened to 218.2 feet (66.5 metres) for additional fuel capacity, and the steering system was enhanced with two rudders for improved turning. Superchargers gave the diesel engines a slight increase in top speed to 17.9 knots surfaced and 8 knots submerged. The U-48 could operate to a crush depth of 656 feet (200m) and was of single pressure hull construction.



Two AEG GU 460/8-276 powered the U-48 up to eight knots while submerged

ENGINE

The pair of supercharged four-stroke, six-cylinder Germaniawerft F46 diesel engines that powered the U-48 while surfaced generated up to 3,160 shaft horsepower and a top speed of 17.9 knots. The engine was widely produced prior to and during World War II. While running submerged U-48 was capable of a top speed of eight knots with two AEG GU 460/8-276 double acting electric motors producing 740 shaft horsepower. Diesel exhaust ports were mounted on the sides of the hull and designed to vent exhaust downward to minimise the submarine's visibility on the surface.

**INTERIOR**

The interior of the Type VII submarine was cramped, as individual comfort was not a priority. The forward torpedo room and sleeping area for junior sailors were located at the bow. Further aft, senior crew quarters and the captain's cabin were atop a separate area where the batteries that powered the electric motors were stowed. The main control room was amidships with the navigator's table, helm control and diving controls. The conning tower was directly above, housing the attack computer, periscope and the exit hatch to the exterior. Further aft were the sleeping area for junior noncommissioned officers, galley, aft head, pantry, batteries, engine room and aft torpedo room.

SPECIFICATIONS

CREW: 44
COUNTRY OF ORIGIN: NAZI GERMANY
COMMISSIONED: 1939
RANGE: 6,500 MILES (12,038km)
SPEED: 17.9kts (32km/h)
LENGTH: 66.5m (218.2ft)
DISPLACEMENT: 753 TONS SURFACED
POWERPLANT: 2x KRUPP DIESEL
ENGINES: 2x AEG ELECTRIC MOTORS
WEAPONS: 5x TORPEDO TUBES WITH
 14 TORPEDOES; 88mm NAVAL GUN;
 20mm ANTI-AIRCRAFT GUN

THE WAR UNDER THE WAVES

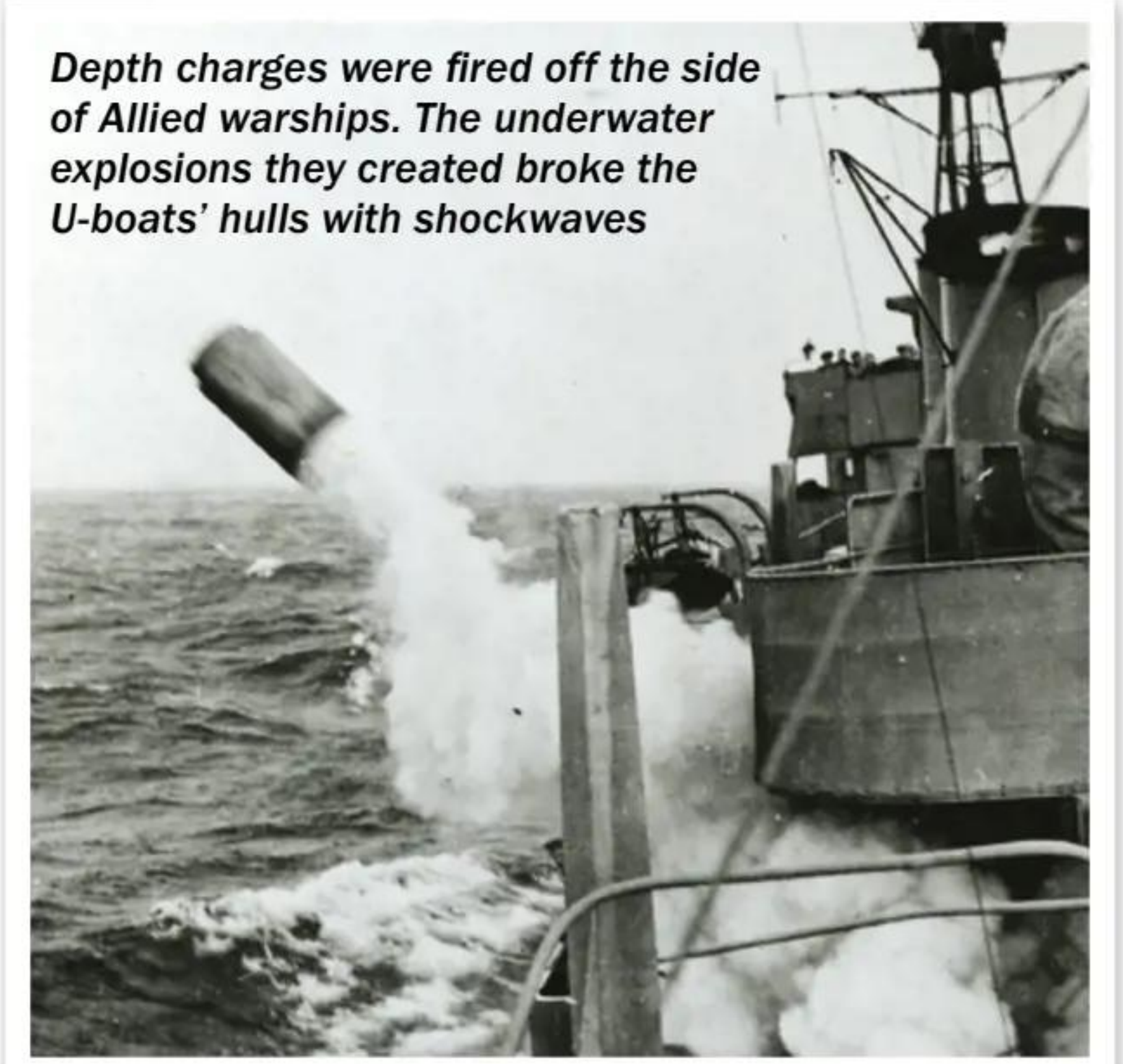
Increasingly sophisticated technology played a key role in determining who emerged victorious from the deadly duel on the high seas

Perhaps more than any battle in history, the one for control of the Atlantic shipping lanes during the Second World War demonstrated the importance of technology in warfare. Since humans first began engaging in organised conflict thousands of years ago, the victors have almost exclusively been those with the technological edge. When World War II began, it was the German navy, which had been preparing for war for years and who in Admiral Dönitz had a master strategist, that looked best prepared for victory. However, Britain, along with its ally Canada and later the US, developed an astonishingly rapid and sophisticated response to the U-boat threat that ultimately proved irresistible.

Dönitz insisted on a top-down command structure, ensuring he micro-managed every single engagement with Allied shipping from his war room, which from the summer of 1940 was in Lorient, Western France. This obsessive planning ultimately made his submarine crews vulnerable to intelligence leaks. With the cracking of Germany's supposedly unbreakable Enigma code in 1941, which Dönitz used to communicate with his U-boat commanders and move his wolf packs around his maritime maps, the fate of Germany's U-boat fleet was sealed. Then, with an array of ground-breaking detection devices and bespoke weaponry, it was eventually destroyed.

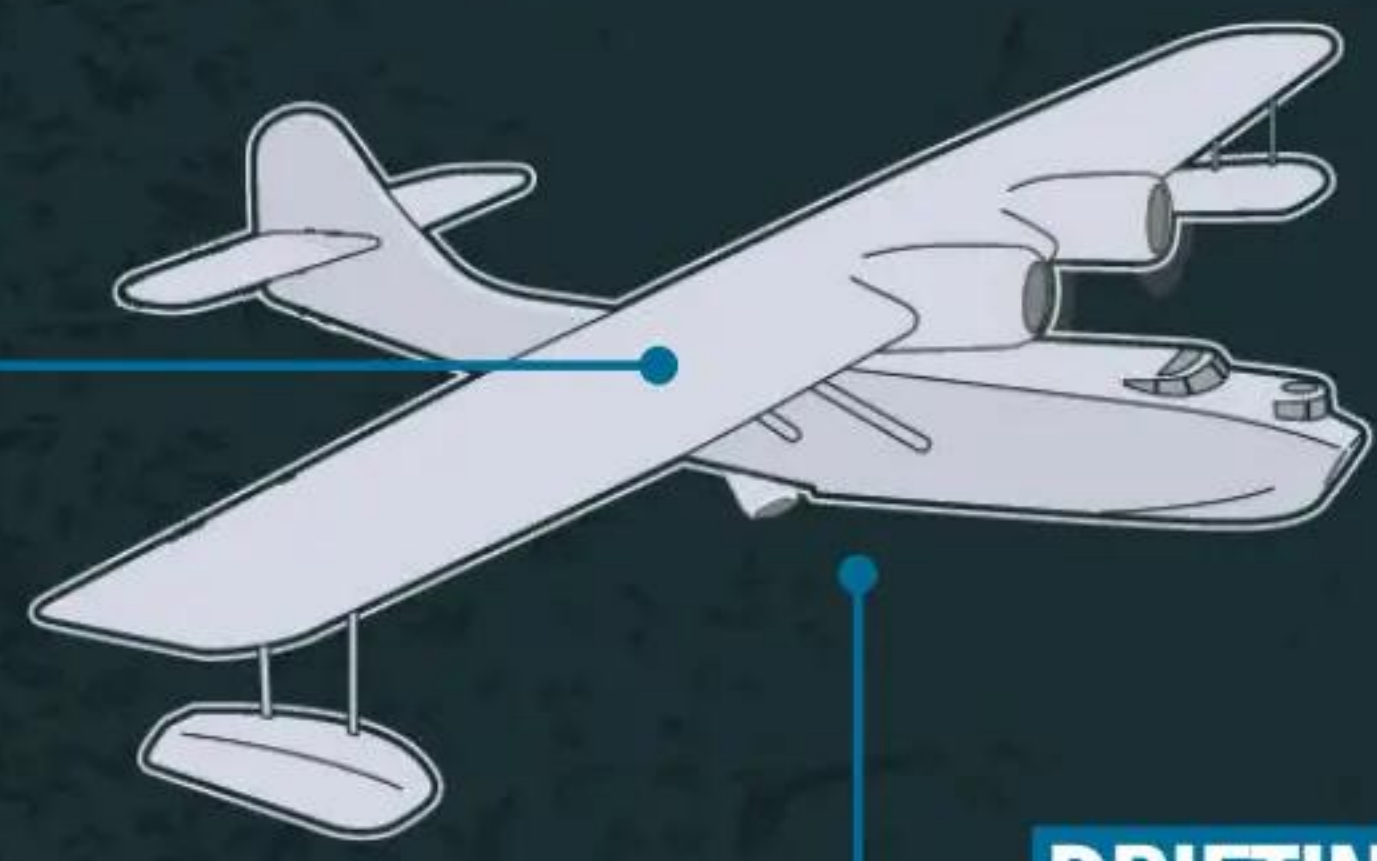


Above: Ramming U-boats was another tactic used by allied naval commanders – often resulting in considerable damage to their own ships



Depth charges were fired off the side of Allied warships. The underwater explosions they created broke the U-boats' hulls with shockwaves

CATALINA FLYING BOAT



LEIGH LIGHT

Dubbed 'the dustbin' because of its shape, this 22-million candlepower, 24-inch retractable searchlight was slung underneath the fuselage of sub-hunting Allied aircraft. When an unsuspecting U-boat was suddenly pounced upon from above while travelling on the surface, the light was switched on and the sub illuminated. This not only made it easier for the attacking aircraft to hit it, but it also blinded the U-boat's crew in the first few vital moments of the attack as they struggled to respond.

DRIFTING/FLOATING MINES



HEDGEHOG

This forward-firing mortar spat groups of 24 missiles up to 820ft (250m) from the deck of a corvette or a destroyer as it chased down a submerging U-boat. Its shells would only explode if they actually made contact with the evading U-boat, which meant the sonar wasn't disturbed if the shell missed. More deadly than depth charges, which relied on hydrostatic shockwaves to score a kill, the hedgehogs' missiles would punch a hole directly into the U-Boat's hull.

RISING MINE



SONAR

The British had developed sonar before the war, using directional sound waves to 'see' underwater. These bounced off the U-boats and were heard back as an echo. The quicker the return of the echo, the closer the submarine. Listened in to by a radio operator, they had a range of about 902ft (275m) – ideal if a submarine was close, less so if it was at the limit of its torpedo range, which in 1939 was about 1.8 miles (3km).

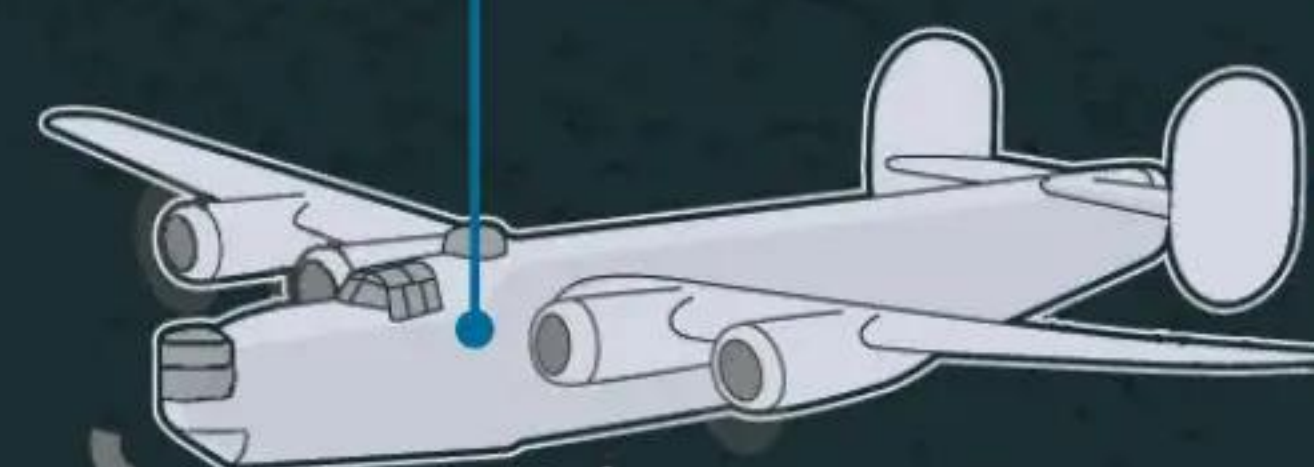
INTELLIGENCE

The work done by Alan Turing and his team of code breakers at Bletchley Park was key to the Allied victory, not just in the Battle of the Atlantic but the entire war. Their cracking of the Enigma code in 1941 enabled the Royal Navy's Western Approaches Command to effectively see every play Dönitz was making as he was making it, and simply steer the convoys away from or around his lurking wolf packs.

THE CONVOY SYSTEM

This was the key way merchant ships making the hazardous trip across the North Atlantic organised themselves. Travelling in large groups, they were protected by 'outriders' from the Royal Navy, the Royal Canadian Navy and the later the US Navy. Although there could be scores of ships in a convoy, because of shortages there were often just four warships accompanying them, which used a combination of sonar and radar to 'watch' for U-boats both above and below the waves.

B24 LIBERATOR



AIRCRAFT

Although aircraft were the U-boats' greatest adversary, early on in the war the Allies had no long-range planes capable of patrolling the entire north Atlantic. An area in the heart of the ocean known as the 'air gap' allowed the U-boats to hunt unhindered. As the war went on, however, planes such as the Consolidated PBY Catalina and bombers like the Consolidated B-24 Liberator were adapted so that they could fly longer distances.

FIDO TORPEDO

The US-built Mark 24 was a 310 kilogram torpedo that used two acoustic transducers (or antennae) that reacted to sound so that it could literally home in on its target. Measuring 7ft (215cm) long and 1.5ft (50cm) wide, it was dropped from aircraft and then, powered by a five-horsepower electric motor, propelled towards its target at a speed of 12 knots (the top speed of Dönitz's U-boats while submerged was just ten knots) delivering a 88lb (40kg) high-explosive warhead.

MOORED MINES



TORPEDO MINE

DESTROYER

The Royal Navy had about 180 destroyers when the war broke out. In the early stages of the conflict, these were the most effective weapon for defending convoys against submarine attacks. Fast moving and more heavily armed than the U-boats, they also had shallow hulls making them particularly difficult for U-boat commanders to torpedo them. By the end of the conflict, a further 277 destroyers had been commissioned, while 153 had been sunk – but only 28 to submarines.

DEPTH CHARGES

As they struggled to keep up with convoys while submerged, the U-boats often attacked on the surface and at night when their slender shape was hard to detect with binoculars. Once engaged by a warship or an aircraft, however, they'd need to dive to survive. Underwater, they were vulnerable to depth-charge attacks from above. These timer-controlled, high-explosive charges were jettisoned into the water in patterns, often exploding simultaneously above and below the submarine, sandwiching it in a blast.

“DÖNITZ INSISTED ON A TOP-DOWN COMMAND STRUCTURE, ENSURING HE MICRO-MANAGED EVERY SINGLE ENGAGEMENT WITH ALLIED SHIPPING FROM HIS WAR ROOM”

YAMATO

JAPAN'S DOOMED FLAGSHIP

In 1945 this super battleship embarked on a desperate mission to halt the American landings on Okinawa



A grey leviathan looms in the midday light. The battleship's great guns are silent but exude a palpable aura of menace. It drives southwards over the waves of the East China Sea at 20 knots towards its final destination, Okinawa, where an armada of American ships lies offshore overseeing the invasion of the island. Yamato, the pride of the Imperial Japanese Navy (IJN), is a 70,000-ton super battleship, the first of her class and flagship of the Combined Fleet. It is far superior to any other warship afloat.

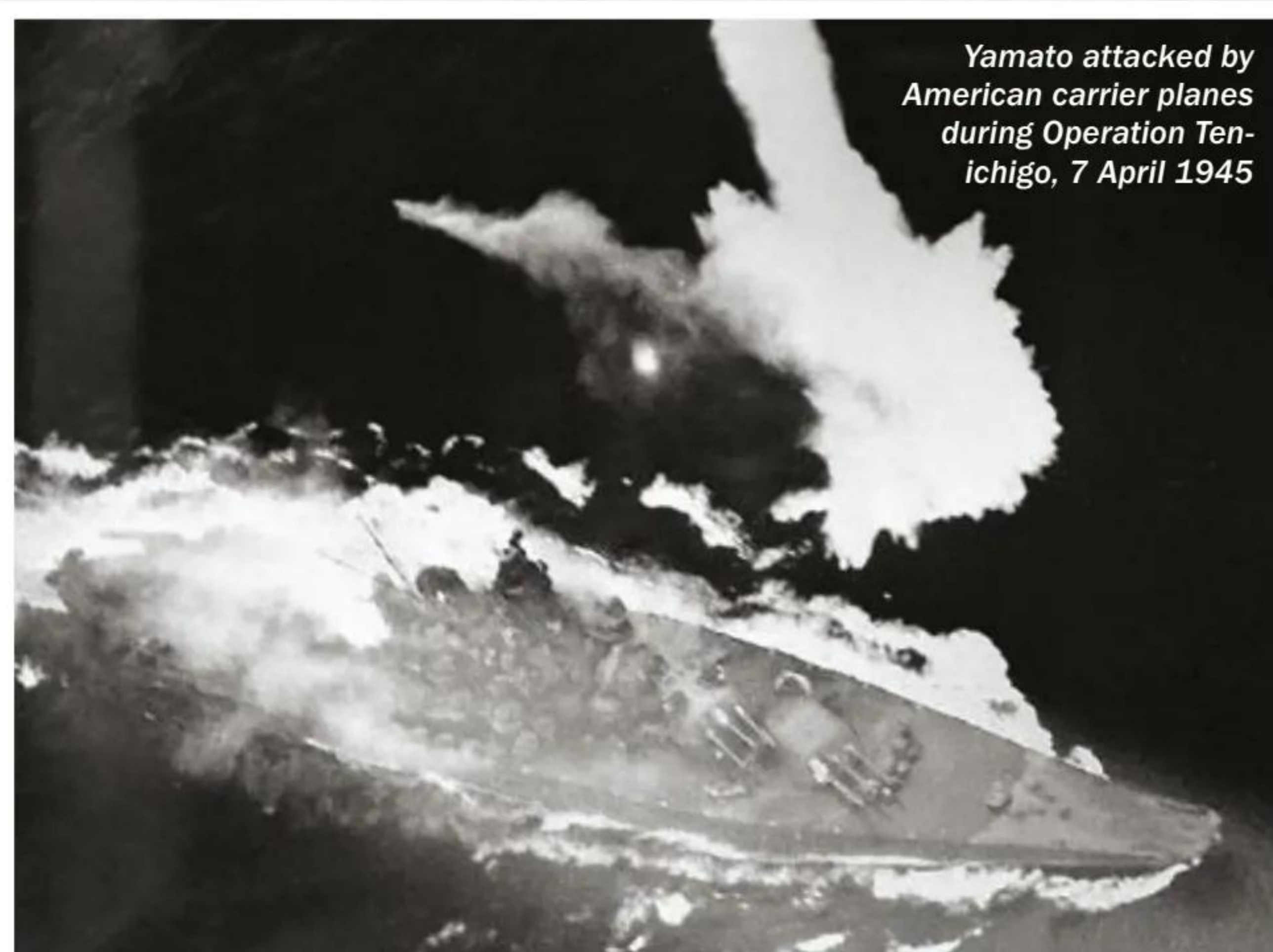
Yamato is under orders to ravage the American ships off Okinawa with her gigantic 18.1-inch (47cm) guns, beach herself and fight to the death in the same spirit as the kamikaze pilots who at that moment exact a frightful toll on the US Navy's warships. Okinawa is an island in the Ryukyu chain, and the last stepping stone for the US forces before the Japanese Archipelago lying 350 miles (560km) away. It is here that the battleship is expected to live up to her name, Yamato – a word that embodies the essence of the Japanese nation and people.

However, the flagship will never reach its destination. It is just past noon, 7 April 1945, and Yamato is still 250 miles (400 kilometres) to the north west of Okinawa. US Navy warplanes have found her. They are circling, visible through gaps in the clouds – midnight-blue angels of death casting judgement over the battleship and her nine escorts. On Yamato's bridge stands a young assistant radar officer, Ensign Mitsuru Yoshida. He is 22 years old and had been a law student at Tokyo Imperial University just two years before, when he was called to serve his emperor. Unlike almost all of his fellows aboard Yamato, he will survive the calamity that is about to befall the vessel. After the war, he will write a eulogy for the doomed ship and her crew.

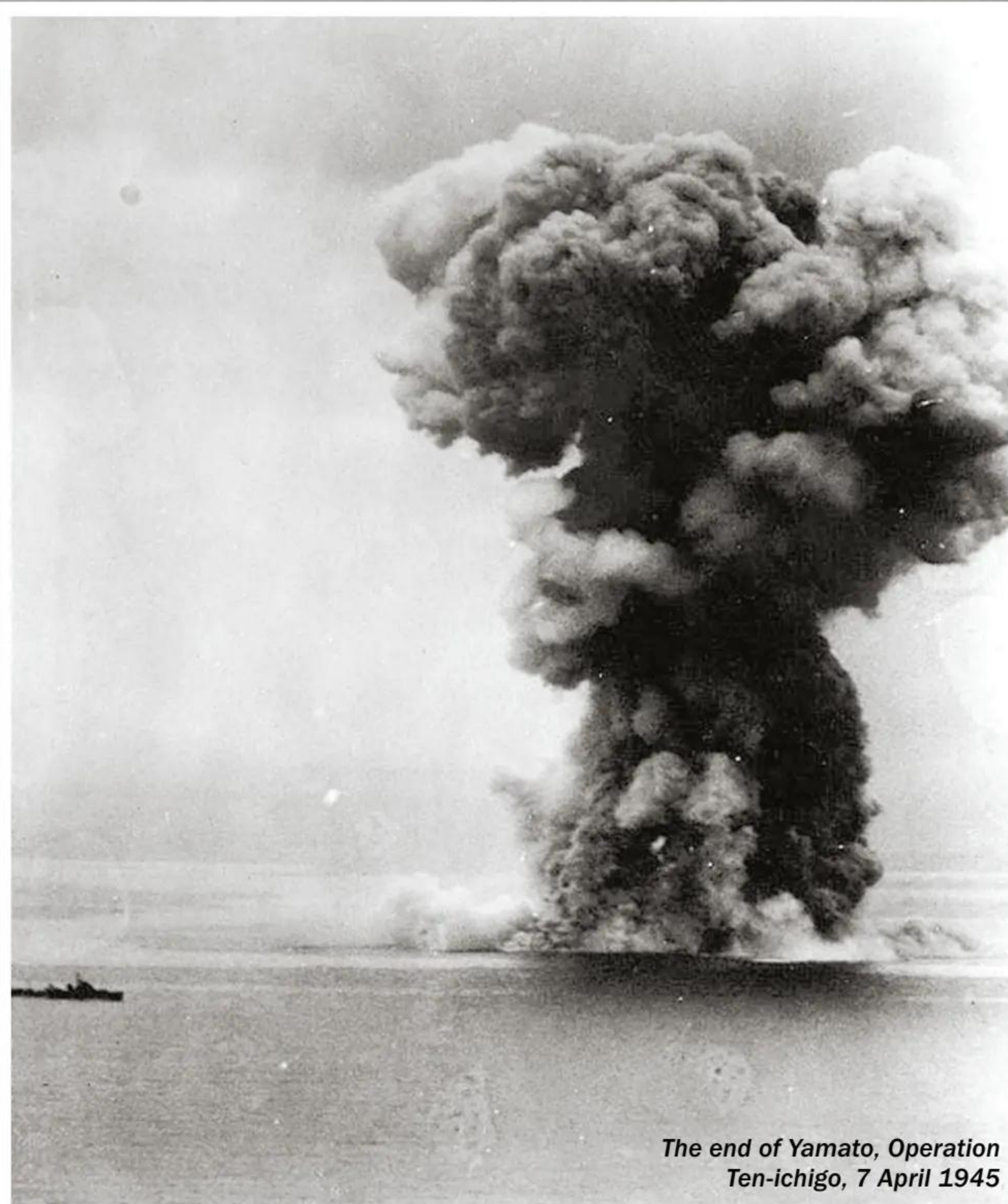
Operation Heaven Number One, or Ten-ichigo in Japanese, has little chance of success. The mission has been conceived as a means of restoring a measure of honour to the Combined Fleet, which has been shamed by its inaction around Okinawa compared to the kamikaze attacks of Japan's death-seeking pilots. "But where is the navy?" Emperor Hirohito asked

Admiral Koshiro Oikawa, his most senior naval adviser, at a 29 March meeting concerning the fighting. "Are there no more ships? No surface forces?" Oikawa was mortified by the implication that the navy, most of whose ships now lie at the bottom of the Pacific Ocean, was not doing enough. So on 6 April Yamato sailed from Kure Harbour to die at Okinawa, covered in glory for the good of the navy. "The fate of the navy rests on this one action," her crewmen were portentously told as they departed.

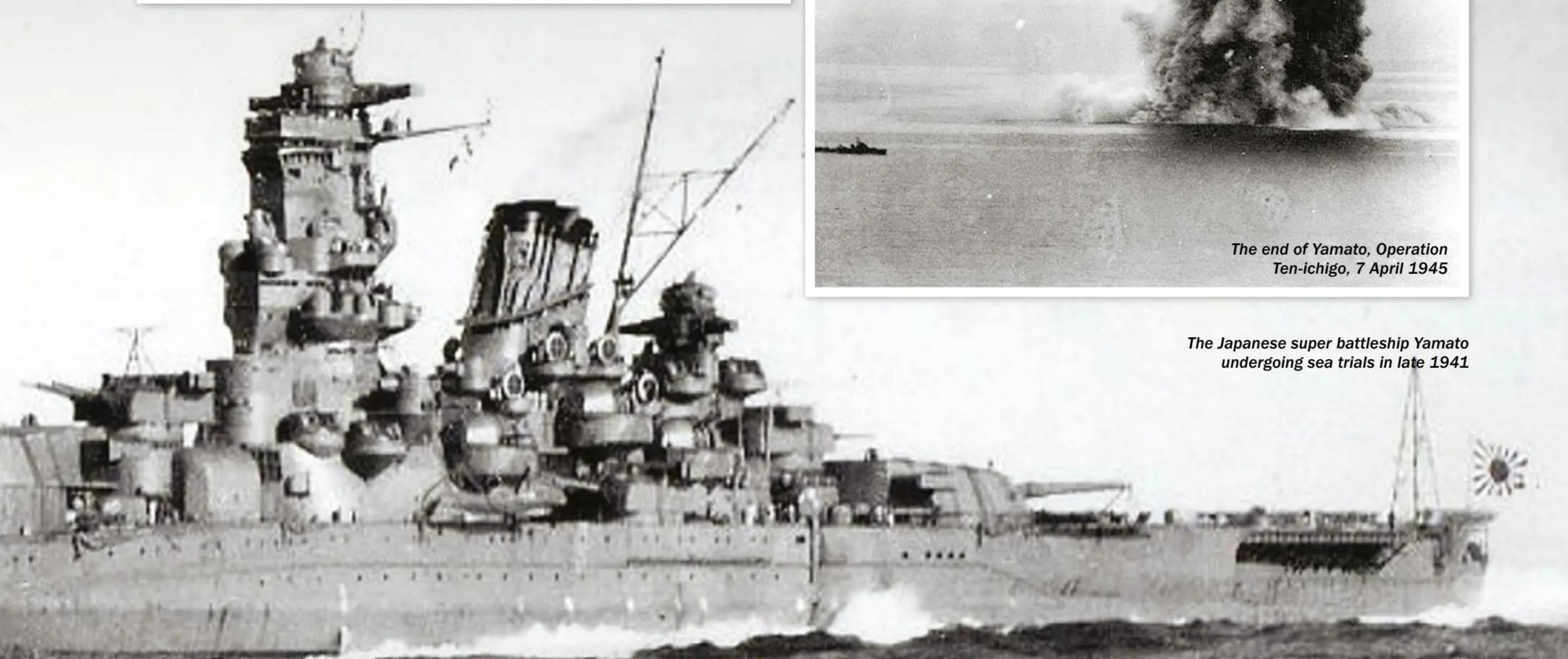
Despite her awesome power, Yamato has seen little combat, having engaged the Americans briefly during the Battle of Leyte Gulf in October 1944. The ship has been outmoded since the start of the Pacific War. The strike on Pearl Harbor on 7 December 1941 proved that aircraft carriers, not battleships, were now the arbiters of war at sea. A mere two days later, the Japanese confirmed the vulnerability of surface warships to aircraft when their planes struck and sank the Royal Navy's HMS Prince of Wales and HMS Repulse. Surface ships, however powerful, were extremely vulnerable to air attack unless themselves protected by



*Yamato attacked by
American carrier planes
during Operation Ten-
ichigo, 7 April 1945*



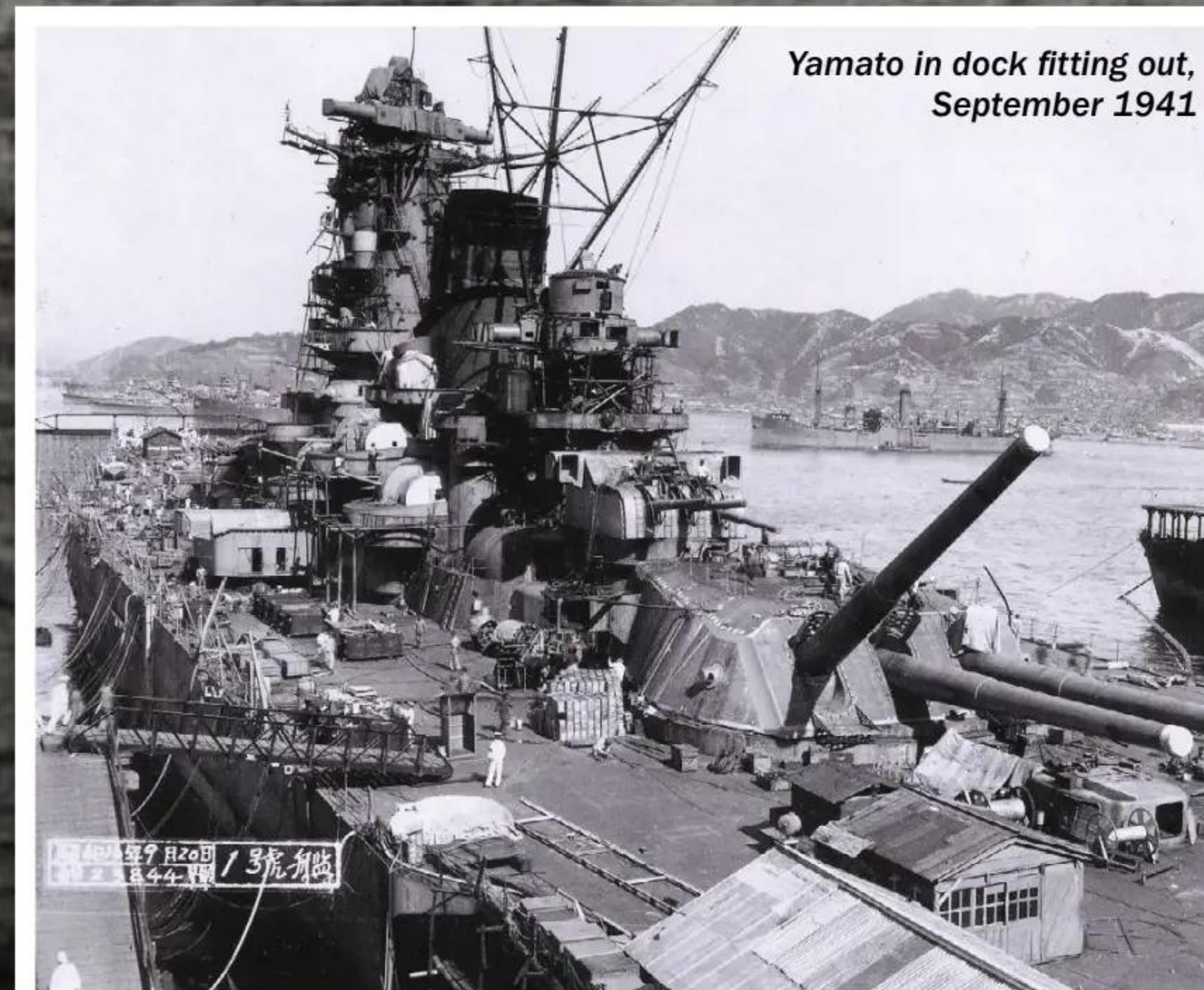
*The end of Yamato, Operation
Ten-ichigo, 7 April 1945*



*The Japanese super battleship Yamato
undergoing sea trials in late 1941*



*Yamato's senior officers prior to the
start of Operation Ten-ichigo*



*Yamato in dock fitting out,
September 1941*

THE MIGHTY BATTLESHIP YAMATO

Yamato was enormous, measuring 863ft (263m) stem to stern. She displaced 70,000 tons and was 40 per cent bigger than the battleships of the Iowa class, the US Navy's largest. Its superstructure, dominated by the mast and raked funnel, was like a fortress bedecked with guns. Enough steel went into the hull to lay a railway track between Tokyo and Osaka. Yamato bore a full load of munitions for all of its weapons on 7 April 1945.

TYPE 96 25MM ANTI-AIRCRAFT GUNS

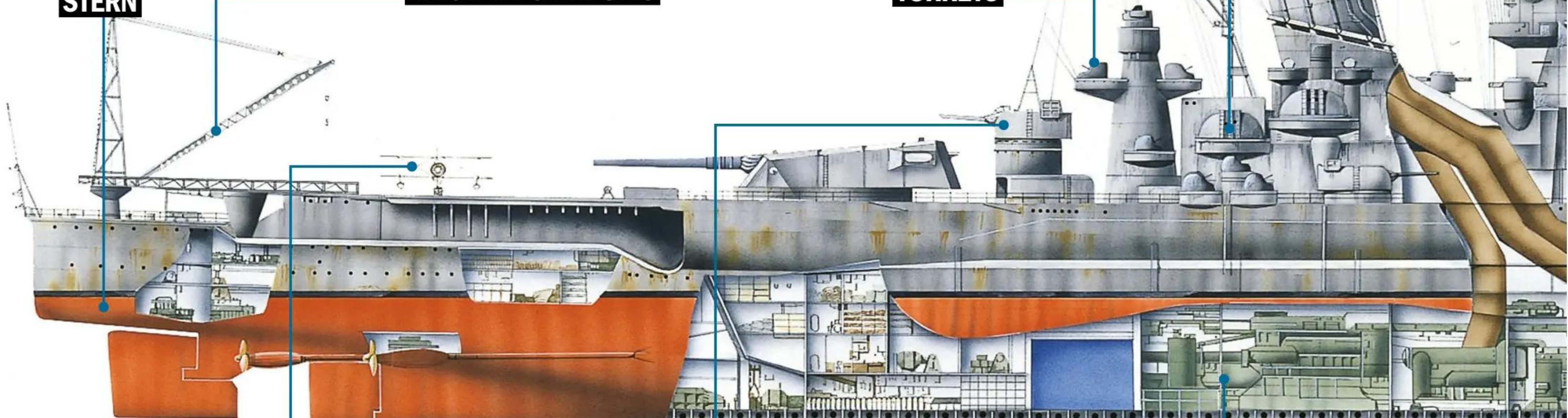
Yamato had 152 Type 96 25mm anti-aircraft guns, with 50 in triple mounts and two single mounts.

FUNNEL

STERN

AIRCRAFT CATAPULTS

TURRETS



NAKAJIMA SCOUT AIRCRAFT

The Yamato embarked seven Nakajima floatplanes to conduct reconnaissance. They were launched from catapults at the stern of the ship.

TYPE 89 127MM GUNS

The Yamato carried six Type 89 twin 127mm naval guns, with three on each side of the citadel.

ENGINES

Yamato was powered through the waves by four propellers connected to four steam turbines and driven by 12 boilers, which produced 150,000 shp. It gave her a top speed above 27 knots (51.5km/h).

fighters, and so for much of the war Yamato has been kept sheltered in home waters, awaiting a decisive battle with American battleships that will never come.

The Surface Special Attack Force is under the overall command of Vice Admiral Seiichi Ito, who uses Yamato as his flagship, while the ship herself is under the direction of Captain Kosaku Ariga. Ito is aghast at what he considers the purposeless waste of his ships and the lives of his men, but he keeps such thoughts from them. Yet the crewmen of Yamato are under no illusion that Ten-ichigo can end in anything besides her destruction. It is a suicide mission. They have been ordered, preposterously, that if they manage to survive long enough to reach the island, they are to arm themselves and go ashore to continue the fight. Many sailors, aware of what is to come, have written their last letters home to their loved ones.

Awaiting Yamato and the ships of the Second Destroyer Squadron that accompanies it on this death ride is the US Fifth Fleet, riding high at the peak of its wartime might. The Yamato crewmen know they have been spotted by an American submarine, but they are deeply upset that the Americans have radioed their position to the rest of the fleet without even encoding the message, as if they are not taking the great battleship seriously enough.

On Yamato, rice balls and black tea are served to the crew, who sing patriotic songs and shout "Banzai!", the traditional Japanese battle cry. Ariga, a popular captain, allows some

of his younger officers to affectionately pat his bald pate. There is a limit to the levity, however. In contemplation of the swarm of American aircraft that is sure to assail them, one sailor asks morbidly but with true prescience, "Which country showed the world what airplanes could do by sinking Prince of Wales?"

Ensign Yoshida finds that one of his fellows, Ensign Sakei Katono, is reading Leo Tolstoy's *War and Peace*, while Yoshida buries himself in a biography of Baruch Spinoza. He also sees that another ensign, Kunio Nakatani, is weeping into his pillow. The assistant communications officer aboard Yamato is a Japanese-American from California who was studying in Japan and had the misfortune to find himself stranded there when the war began. He has received, at long last – just before Yamato sailed on her final voyage – a letter from his mother in America, that reaches him via neutral Switzerland. He will never see her again.

A reconnaissance plane operating off the aircraft carrier USS Essex spies the flotilla at 8.15am on 7 April. Over the following four hours, the Americans doggedly track Yamato and the

other ships of the flotilla. Admiral Raymond Spruance, commanding officer of the Fifth Fleet at Okinawa, at first decides to keep his carrier fighters close by to provide cover against the swarming kamikazes and instead sends a powerful squadron of battleships to confront the onrushing Japanese ships. Yamato, it seems, will finally get to fulfill her purpose and duel valiantly with her American peers.

Then Spruance cancels his order. Vice Admiral Marc Mitscher, the commander of the carrier aircraft of Task Force 58, convinces him that his planes will be better dealing with the immense Japanese warship. At 10.00am 280 planes from no fewer than ten aircraft carriers launch themselves into the leaden Pacific sky, destined for a fateful rendezvous with the approaching Yamato.

At 12.00pm Admiral Ito sits on the bridge of Yamato and smiles. He says cheerfully, "We got through the morning all right, didn't we?" The battleship's good fortune will not last long. Just 20 minutes later Yamato's air search radar detects the approaching American aircraft. The Japanese ships are bereft of fighter cover. Their only defences will be the anti-aircraft guns aboard. Then the attacks begin – the first wave of many in a sea of fire and smoke.

Yamato's anti-aircraft batteries and those of her escorts open up in defence. The ferocious fire sent skyward – a prismatic, tracer-lit torrent of searing metal – does the Japanese ships little good. The Americans manoeuvre their machines with great skill. Yoshida grimly

"ITO IS AGHAST AT WHAT HE CONSIDERS THE PURPOSELESS WASTE OF HIS SHIPS AND THE LIVES OF HIS MEN"

RADAR

Three different radar sets were carried by the battleship, including a Type 13 air search radar, Type 21 air and surface search radar and a Type 22 surface search radar.

TOWER**CITADEL****MAIN GUNS**

The main armament of Yamato consisted of nine Type 94 18.1 inch (46cm) naval cannons mounted in three turrets. These guns, each weighing 162 tons, were the largest ever emplaced on a ship, and were capable of hurling a 3,200lb (1,400kg) shell to a maximum range of 2.5 miles (4km). The ship carried 1,080 of these. Each triple turret weighed a hefty 2,774 tons.

ARMOUR

The Yamato possessed substantial protection, carrying 22,500 tons of armour – the most ever placed on a warship. Covering the armoured citadel was a 16-inch (41cm) main belt of armour that extended below the waterline. The lower belt that protected the ammunition magazines was 11 inches (28cm) thick. The three main gun turrets had frontal armour of 26 inches (66cm) thickness, while the deck had armour of up to 9 inches (23cm).

BOW**155MM DUAL-PURPOSE NAVAL GUNS**

The secondary armament of Yamato consisted of 12 155mm cannons in four triple gun turrets. They were capable of taking on targets in the air and on the surface.

CREW

The Yamato required an enormous crew of some 3,300 men to operate her. Most were berthed below deck ahead of the forward turrets. Crew accommodations were relatively generous, earning her the nickname 'Hotel Yamato'.

observes that their highly trained pilots fly in a straight course only long enough to drop their bombs or torpedoes, then hurriedly zigzag away. The sheer number of aircraft also works in the Americans' favour, as the Japanese gun crews find themselves overwhelmed with a multiplicity of fast-moving targets.

In all, 364 American carrier aircraft pounce on Yamato and the ships in her escort. The light cruiser Yahagi, the lead ship of the Second Destroyer Squadron, goes down after being struck by seven torpedoes and 12 bombs, while US aircraft also hammer the destroyers. It is Yamato, however, that receives the greatest attention from the American fliers. They concentrate their torpedo strikes on the port side of the ship to cause her to list quickly.

Wave after wave of Avenger torpedo bombers and Helldiver dive bombers, protected by Corsair and Hellcat fighters, surge over Yamato. Yamato's executive officer, Rear Admiral Nobii Morishita, can't help but admire the professional competence of the attackers. 'Beautifully done, isn't it?' he says. She is hit by one torpedo after another. Between 11 and 13 strike her, together with no fewer than eight bombs. There are many more near-misses, and she lists worryingly to port. She takes on thousands of gallons of seawater to counter the listing, but to little avail. The waves crash over her port side. At 2.10pm a bomb strikes her rudder, damaging it and knocking out all power in the ship. She can no longer manoeuvre. Yoshida spies a thin, human-sized length of

flesh dangling from a rangefinder. Her crew has been equally savaged.

Another wave of enemy planes bears down on Yamato. "Don't lose heart," Captain Ariga keeps urging the surviving men on the bridge. But there is no hope for Ten-ichigo. Admiral Ito's flotilla has been shredded by American airpower to no purpose, just as he had expected. Like Yahagi, most of the destroyers have been smashed. He calls off the operation and commands his remaining ships to return home after picking up survivors of disabled ships. After giving this order, he goes to his cabin and closes the door behind him. He will never emerge. Captain Ariga calls his crew to Yamato's deck as water floods the stricken vessel and orders them to abandon ship. He will not be joining them, but binds himself to a binnacle so that he will go down with his ship. "Long live the emperor!" he cries.

Yamato's severe list is now reaching an astonishing 90 degrees to port. As she continues to roll, the giant shells she stows for her main guns slip and slide in their magazines, their fuses striking bulkheads and overheads. They begin to detonate.

By 2.23pm Yamato is completely upside down and begins to sink. The greatest of these

blasts consumes her, sending up a mushroom cloud of fiery smoke.

Ensign Yoshida is indescribably lucky. The plunging Yamato was about to pull him under in its whirlpool when this final explosion propels him back to the surface. He will live. The remains of the battered Yamato finally sink in 2,700 feet (883 metres) of water. Yoshida, who will become a bank executive after the war, is plucked from

the oil-choked water by the destroyer Fuyutsuki. He writes his *Requiem for Battleship Yamato* years later, calling Ten-ichigo "An operation that will live in naval annals for its recklessness and stupidity."

The Japanese loses seven ships in Ten-ichigo, including Yamato, along with 4,250 sailors. Only three destroyers escape. The US Navy's losses are much lighter – a mere ten warplanes and 12 airmen. When the Emperor learns of the failure of the operation and the loss of Yamato, he raises

his hand to his head and sways. "Gone?" he says in shocked disbelief. "She's gone?"

The Okinawa invasion will not be stopped. It continues until late June, when the last Japanese resistance is crushed. Of the 3,300 crewmen of Yamato, just 269 survive. Her dead are the among the first casualties in the Okinawa campaign. They are not the last.

SPECIFICATIONS

CREW: 3,300
COUNTRY OF ORIGIN: IMPERIAL JAPAN
COMMISSIONED: 1941
SPEED: 27kts (51.5km/h)
LENGTH: 863ft (263m)
DISPLACEMENT: 70,000 TONS
POWERPLANT: 4x STEAM TURBINES
WEAPONS: 9x 46cm CANNONS; 12x 155mm CANNONS; 6x TWIN 127mm NAVAL GUNS; 152x 25mm AA GUNS

BELGOROD-CLASS SUBMARINE

The Russian Navy’s Belgorod-class nuclear submarine brings new dimensions in operational capability to the nation’s armed forces

On 1 March, 2018, Russian President Vladimir Putin delivered his annual State of the Nation address to his people and the world. Putin affirmed the existence of six new nuclear weapons systems intended to provide cutting edge capabilities in modern military operations.

Among the systems affirmed was the Belgorod-class nuclear submarine, designed to provide second strike capability through its complement of six Poseidon nuclear-powered and nuclear-armed torpedoes as well as serving as a mother ship for the unmanned Losharik or Paltus mini-submarines.

During a speech delivered at St. Petersburg in April 2019, Putin again highlighted the potential of the Belgorod-class submarine, declaring, “Together, we will inevitably maximize Russia’s status as a great naval power.” With the retirement of the fabled Typhoon-class nuclear submarines, the Belgorod is believed to be the longest submarine ever built.

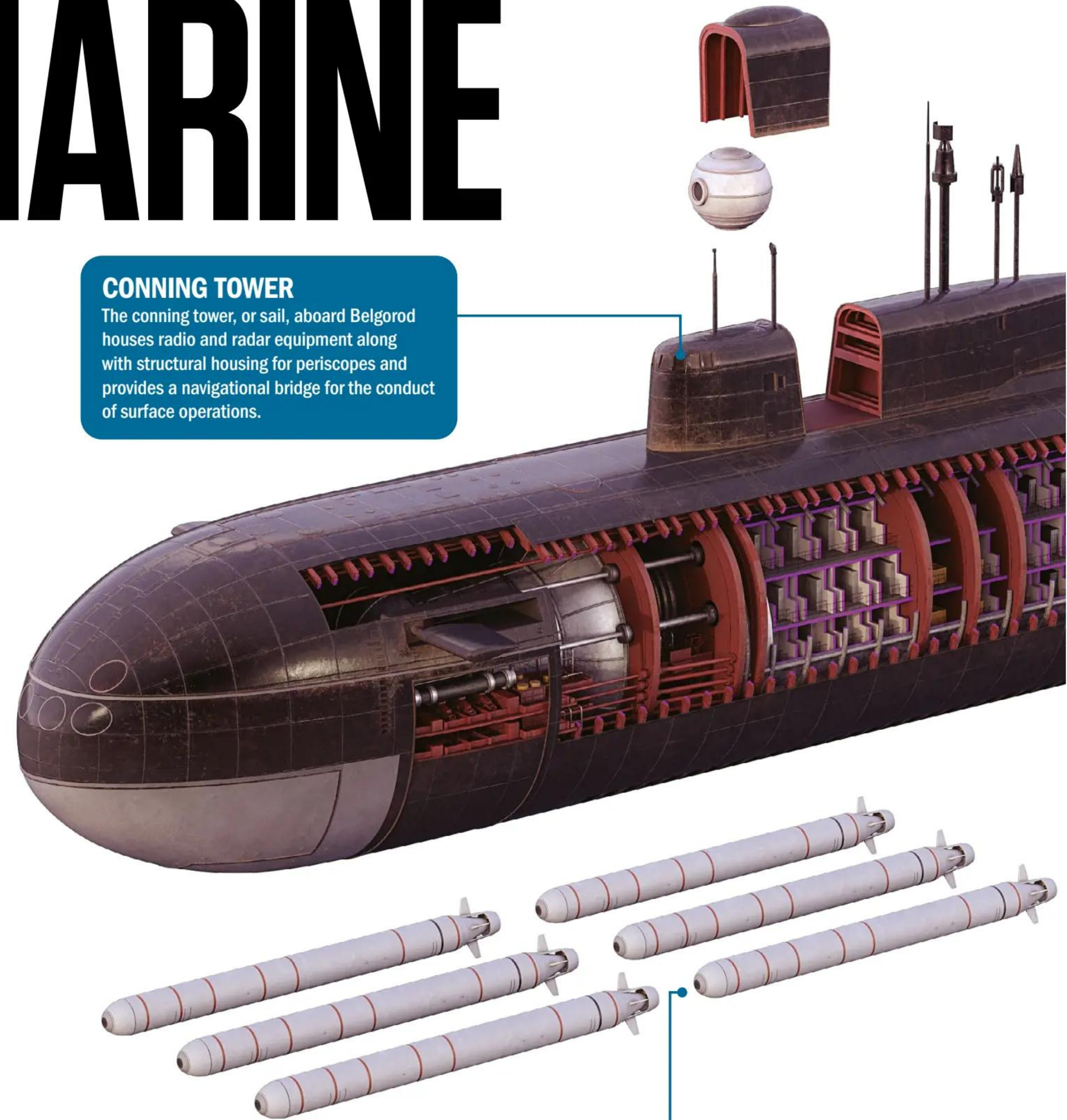
The Belgorod’s winding road from concept to service spans three decades. The submarine’s development worked through fits and starts due to the economic distress in the post-Soviet era as well as challenges in design and setbacks that occurred with its weapons and operational systems. At the same time, shadowy knowledge of this single submarine’s existence has sparked concerns among Western observers.

CONNING TOWER

The conning tower, or sail, aboard Belgorod houses radio and radar equipment along with structural housing for periscopes and provides a navigational bridge for the conduct of surface operations.

MAIN ARMAMENT

Belgorod carries six Poseidon nuclear missile systems, each the size of a bus and approximately 80 feet long. The Poseidon warheads are reported to deliver a yield up to 100 megatons.



Admiral Nikolai Yevmenov, then commander-in-chief of the Russian fleet, remarked in the autumn of 2022, “The Belgorod submarine opens up new opportunities for Russia in conducting various research and allows conducting diverse scientific expeditions and rescue operations in the most remote areas of the world’s oceans. The ship is designed to solve diverse scientific problems...and can also be used as a carrier of rescue deep-sea and autonomous unmanned underwater vehicles.” With Admiral Yevmenov’s statement comes the implicit warning of a new frontier in naval warfare proficiency.

DESIGN

The nuclear submarine Belgorod was developed from an originally intended Oscar II-class nuclear cruise missile submarine. A substantial redesign led to lengthening of the hull from just over 505 feet to more than 603 feet, making Belgorod, also designated K-329, the world's longest in current operation. Further, in 2017 the removal of the cruise missile launch bay was undertaken to install a new structure to accommodate a single mini-submarine, either Losharik or Paltus type, along with lengthening of the bow to fit the Poseidon nuclear torpedo weapons system. These comprehensive redesign efforts were completed after several pauses and redirections in construction.

“SHADOWY KNOWLEDGE OF THIS SINGLE SUBMARINE’S EXISTENCE HAS SPARKED CONCERNS AMONG WESTERN OBSERVERS”

POWERPLANT

The nuclear submarine Belgorod is powered by a pair of nuclear reactors using pressurized water in the fission process. The reactors are the latest generation of the proven OK-650 reactor, which feed two steam turbines.

EXTERNAL PROPULSION

The powerplant of Belgorod drives a pair of shafts and two external propellers that generate 250,000 shaft horsepower and top speed of 32 knots while the submarine is capable of unlimited range and operating submerged for 40 straight days.

SECONDARY ARMAMENT

Ostensibly utilized for research and rescue purposes, the mini-submarines of either Paltus or Losharik design may also provide an offensive capability in times of conflict. A fire aboard Losharik in 2019 slowed the Belgorod program.

CREW SPACES

Crew spaces aboard the Belgorod are designed to facilitate extended operations with its lengthened hull providing internal space volume that exceeds other submarine types. Comparatively speaking, the Belgorod's quarters are more accommodating and livable than those of earlier Soviet era and Russian Navy submarines. Some recreational facilities, including a sauna, gymnasium, extensive galley, and other amenities are believed to be provided although space constraints remain a concern amid the submarine's requirements for its Poseidon missile system and capacity to carry a mini-submarine. The quarters are configured for the crew of both Belgorod and that of the accompanying mini-submarine during such missions.

POWERPLANT

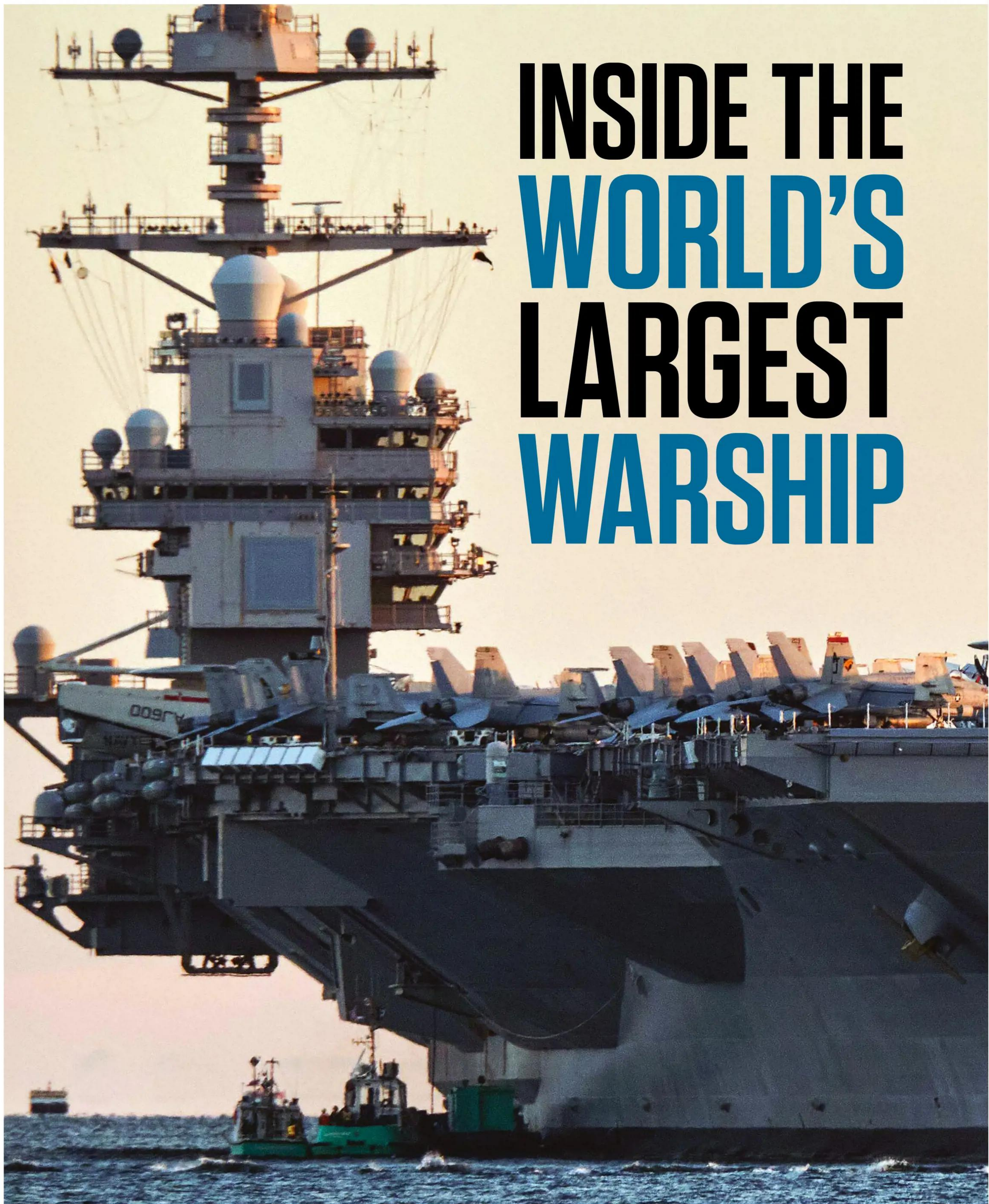
The OK-650 pressured water nuclear fission reactor has powered a least six different classes of Russian Navy submarines across three to four generations of revised performance. The reactor utilizes 20 to 45 percent enriched Uranium 235 and entered service with the Soviet military in the 1970s, having undergone various improvements since that time, including advanced systems to monitor against accidents and provide swift detection of any radiation leaks. The twin reactors aboard the Belgorod are linked with two steam turbines that deliver 250,000 shaft horsepower driving a pair of screws and generating a top speed of approximately 32 knots, or 37 miles per hour.

SPECIFICATIONS

CREW: 25
COUNTRY OF ORIGIN: RUSSIA
COMMISSIONED: 2022
RANGE: UNLIMITED
SPEED: 32kts (59km/h)
LENGTH: 603ft (184m)
BEAM: 49ft (15m)
DISPLACEMENT: 14,700 TONS SURFACE;
30,000 TONS SUBMERGED
POWERPLANT: 2x OK-650M.02
PRESSURIZED WATER NUCLEAR REACTORS;
2x STEAM TURBINES
WEAPONS: 6x POSEIDON NUCLEAR
TORPEDOES; 1 MINI-SUBMARINE

Illustration: Nicholas Fordor

INSIDE THE WORLD'S LARGEST WARSHIP



Step aboard the USS Gerald R. Ford aircraft carrier and see how it compares to other giant warships

An order to protect a country at sea, a naval force doesn't rely solely on ships. Aircraft carriers are large warships that serve as a platform for military planes to take off from and land on, and they are so efficient that aircraft can be launched every 25 seconds from them. To be considered an aircraft carrier, all a ship needs is a runway on its upper deck. But as these vessels have evolved since the early 1900s, ships such as the Gerald R. Ford, the latest class in a long line of US Navy carriers, are decked out with an assembly of machine guns, missiles, submarines, fighter jets and helicopters. These assist the US Navy during rescue operations, weather observations, air-to-air combat and submarine and ocean surface attacks.

It was during World War II that the world's navies came to appreciate the advantages of aircraft carriers. Being able to transport aircraft closer to an overseas target made it possible to initiate devastating air operations. The Japanese Navy, for example, was able to attack Pearl Harbor, Hawaii, from the air in 1941. Because mainland Japan was 4,000 miles away from Pearl Harbor, without their aircraft

carriers this attack wouldn't have been possible – Japan's Air Force would have run out of fuel long before reaching Hawaii.

Since World War II, aircraft carriers have increased substantially in size. The Gerald R. Ford-class carrier is owned by the US Navy, and when fully loaded weighs 100,000 tonnes. Being nuclear powered, this new class can theoretically operate at sea for around 20 years before needing to be refuelled. However, supplies for the thousands of crew members on board need to be taken into account, and most missions last for a few weeks or months. It's estimated that the Gerald R. Ford carrier has a total operational service time of 50 years.

Planes can be seen on deck



WHO WAS GERALD FORD?

The name of this class of aircraft carrier was chosen to honour the 38th US president and the work he undertook as part of the navy. Future president Gerald Ford signed up for the US Navy as a young man in 1941, after Pearl Harbor was attacked in World War II. Upon completing his training, Ford was sent on sea duty in May 1943 and became the assistant navigator on board the USS Monterey. Ford came close to becoming one of around 800 crew members who lost their lives during a typhoon on 18 December 1944, when the Monterey was severely damaged. After the Monterey was declared unfit for naval service, Ford continued working in the navy as an athletic officer.

On 3 October 1945, Ford was promoted to Lieutenant Commander. During his service in the navy, Ford led operations in the Gilbert Islands, Bismarck Archipelago, Marshall Islands, Hollandia, Mariana Islands, Caroline Islands, Western New Guinea and Leyte. After resigning from the navy in 1963, Ford became president of the US from 1974 to 1977. When the Gerald R. Ford-class carriers were announced, secretary of the navy Donald Winter expressed the navy's admiration for the former president. Winter said that he was "honoured to have the opportunity to name the first ship in the new class of aircraft carriers after this great sailor, this great leader, this great man."

Below: President-to-be Gerald Ford pictured on board the USS Monterey in 1935



21st Century

USS GERALD R. FORD

READY ROOMS

Crews use these rooms for briefings before and after flight missions.

ISLAND

This is the ship's command centre for all activity taking place on the flight deck and the pilothouse for ship navigation.

MAIN DECK

Extending from bow to stern, the main deck is 1,092-feet (333 metres) long.

AIRCRAFT ELEVATOR

The ship's three elevators can lift up to 10,900 kilograms each.

MISSILE LAUNCHERS

Guided missiles are armed and launched on the aircraft carrier.

DUAL-BAND RADAR

The air-search radar can search for objects at sea and in the sky using two bands. The S-band radar is less precise but works well in bad weather, while the X-band is more accurate.

ENGINE ROOM

The A1B nuclear reactor provides the aircraft carrier with electrical and propulsion energy.

MAIDEN VOYAGE

On 4 October 2022, the USS Gerald R. Ford departed for its first deployment. The ship left Norfolk on a mission to carry out training exercises and equipment demonstrations in the Atlantic Ocean. Alongside NATO allies Canada, Denmark, Finland, France, Germany, the Netherlands, Spain and Sweden, training included a total of nine countries, 20 ships and 60 aircraft. One of the desired outcomes of

this deployment was to show strength in unity and improve relations among NATO navies. The aircraft carrier departed for two months, with much of the training involving air defence tactics and subsurface warfare. A primary focus of the initial sail was to practise coordinating vessels from different countries to work effectively as one group, ready for if a real threat were to emerge at sea.



Flight operations being observed on board the USS Gerald R. Ford

US NAVY AIRCRAFT CARRIER EVOLUTION



The USS Langley was the US Navy's first aircraft carrier.

1912

The Lexington-class was the first aircraft carrier to have a bulbous bow – one that protruded underwater.

1925



The USS Ranger was the only carrier in its class and was the first to be built from the keel – the ship's structural beam – up.

1933

Yorktown-class aircraft carriers were the first to have hydraulic catapults.

1936



Essex-class ships could hold up to 100 aircraft.

1944



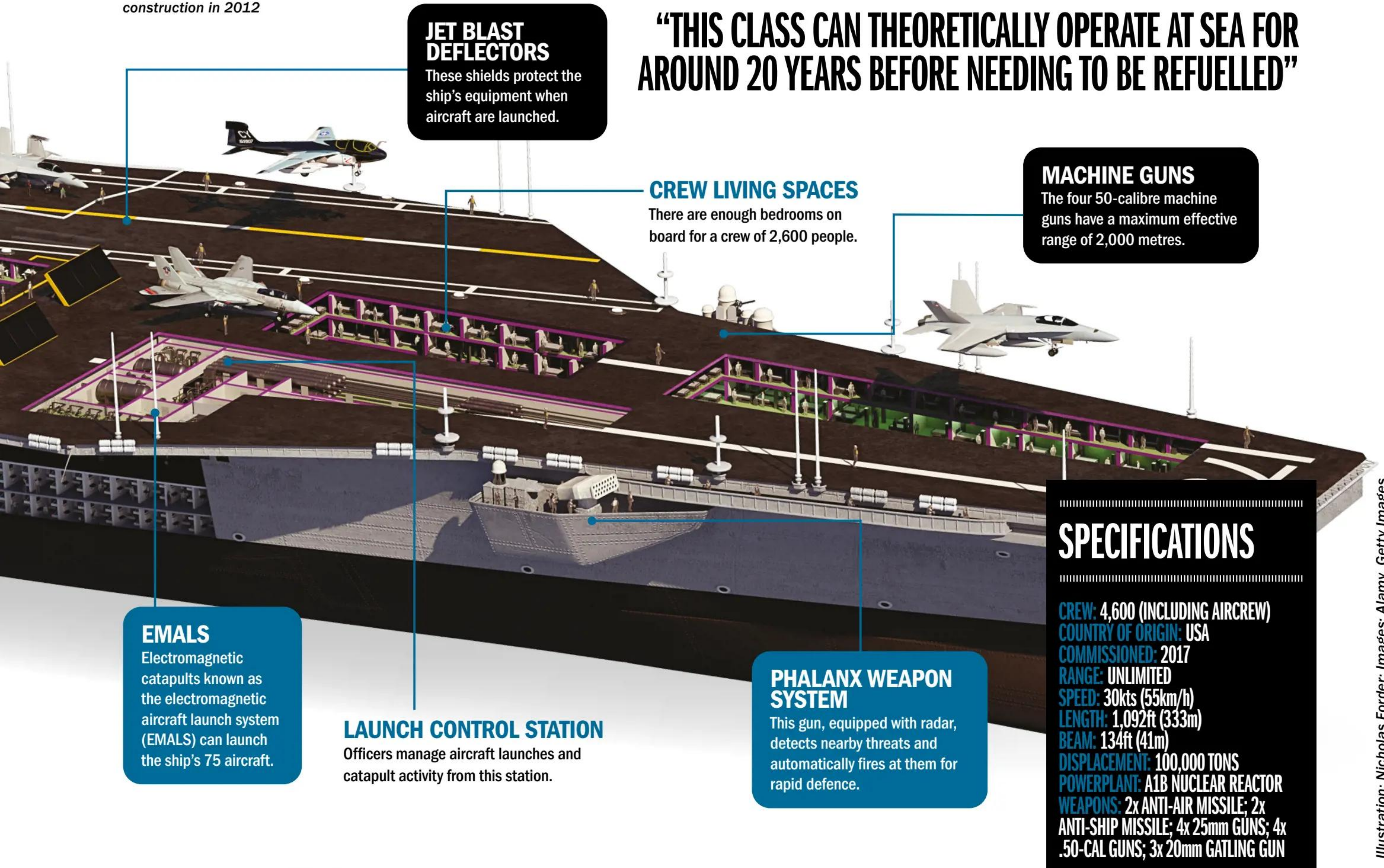
Above: USS Gerald R. Ford under construction in 2012



The commissioning ceremony in 2017 at Naval Station Norfolk



Flight deck and combat air-traffic control centre certification in 2020



JET BLAST DEFLECTORS

These shields protect the ship's equipment when aircraft are launched.

"THIS CLASS CAN THEORETICALLY OPERATE AT SEA FOR AROUND 20 YEARS BEFORE NEEDING TO BE REFUELLED"

CREW LIVING SPACES

There are enough bedrooms on board for a crew of 2,600 people.

MACHINE GUNS

The four 50-calibre machine guns have a maximum effective range of 2,000 metres.

EMALS

Electromagnetic catapults known as the electromagnetic aircraft launch system (EMALS) can launch the ship's 75 aircraft.

LAUNCH CONTROL STATION

Officers manage aircraft launches and catapult activity from this station.

PHALANX WEAPON SYSTEM

This gun, equipped with radar, detects nearby threats and automatically fires at them for rapid defence.

SPECIFICATIONS

CREW: 4,600 (INCLUDING AIRCREW)
COUNTRY OF ORIGIN: USA
COMMISSIONED: 2017
RANGE: UNLIMITED
SPEED: 30kts (55km/h)
LENGTH: 1,092ft (333m)
BEAM: 134ft (41m)
DISPLACEMENT: 100,000 TONS
POWERPLANT: A1B NUCLEAR REACTOR
WEAPONS: 2x ANTI-AIR MISSILE; 2x ANTI-SHIP MISSILE; 4x 25mm GUNS; 4x .50-CAL GUNS; 3x 20mm GATLING GUN

Illustration: Nicholas Forde; Images: Alamy, Getty Images

The first armoured flight deck was constructed for Midway-class carriers.

1945

Forrestal-class aircraft carriers were the first supercarriers. These are ships that displace at least 65,000 tonnes.

1954

The USS Enterprise was the first nuclear-powered aircraft carrier.

1960

The USS John F. Kennedy was the last non-nuclear-powered aircraft carrier made.

1967

The Gerald R. Ford's predecessor, the Nimitz-class, needed 600 more crew on board to operate effectively.

1972

Gerald R. Ford carriers convert steam into electricity using nuclear turbines.

2013



**"SUBMARINES HAVE
COME A LONG WAY
SINCE THE HUMAN-
POWERED VESSELS
OF THE PAST"**

SUPER SUBMARINES

The incredible tech powering the war beneath the waves

Lurking in the depths, hundreds of submarines are currently patrolling the world's oceans, performing a range of very important – and often covert – missions. These stealthy vessels were first widely used during World War I, with Germany's U-boats responsible for destroying several British supply ships during the conflict, and have since changed the face of naval warfare forever.

Always referred to as boats rather than ships as a matter of naval tradition, submarines have come a long way since the human-powered vessels of the past. Most modern submarines use either diesel-electric propulsion or nuclear reactors to keep them running. The former are equipped with diesel engines to drive the submarine's propellers and charge its batteries while on the surface. Then, when submerged, those batteries power electric motors that spin the propellers to move it through the water.

The need to recharge the batteries and replenish fuel for the engines gives these submarines a limited range, so many navies prefer nuclear-powered vessels instead. These boats can stay underwater for weeks at a time, using nuclear fission to release energy in the form of heat, which in turn generates steam to drive a turbine and spin the propellers.

Now crucial tools for navies large and small, submarines transport crews all over the world, sneaking up on enemy ships, launching missiles, and gathering information while remaining hidden in dark, murky waters. They can generally be divided into two categories: attack submarines, which are designed to seek and destroy enemy ships, and ballistic missile submarines, which attack land-based targets.

The US Navy currently has approximately 68 submarines in active service, 54 of which are attack vessels.

It's not just the military that uses these clever underwater crafts, though. With scientists knowing more about outer space than they do about the world's oceans, submarines are incredibly useful for studying marine environments, at depths too great for human divers to reach alone.

In recent years, new unmanned underwater vehicles (UUVs) have begun appearing in the water, capable of conducting dangerous missions while human crews remain safely on the shore or a nearby ship. These vehicles are small with a limited range, but in the future they could replace the submarines we know today.



The unmanned Boeing Echo Voyager

SUBMARINES: IN DEPTH

Major milestones in the development of underwater vessels

DREBBEL I

The first submarine was invented by Dutch engineer Cornelius Drebbel. It was an enclosed wooden rowing boat covered with watertight greased leather and had air tubes protruding to the surface to supply oxygen.

MAX SPEED:
Unknown

RANGE:
3 hours



1620

MAX DEPTH:
4.5m

CREW: 16

TURTLE

The first recorded submarine attack was during the American War of Independence. A Turtle was used in an attempt to blow up the HMS Eagle, but the pilot was unable to attach the bomb to the ship's hull.

MAX SPEED:
5kph

RANGE:
30 mins



1776

MAX DEPTH:
Unknown

CREW: 1

NAUTILUS

American inventor Robert Fulton's submarine was driven by a hand-cranked propeller, but a collapsible mast and sail provided the propulsion. It was commissioned by Napoleon to use against the British.

MAX SPEED:
7kph

RANGE:
6 hours



1800

MAX DEPTH:
7.5m

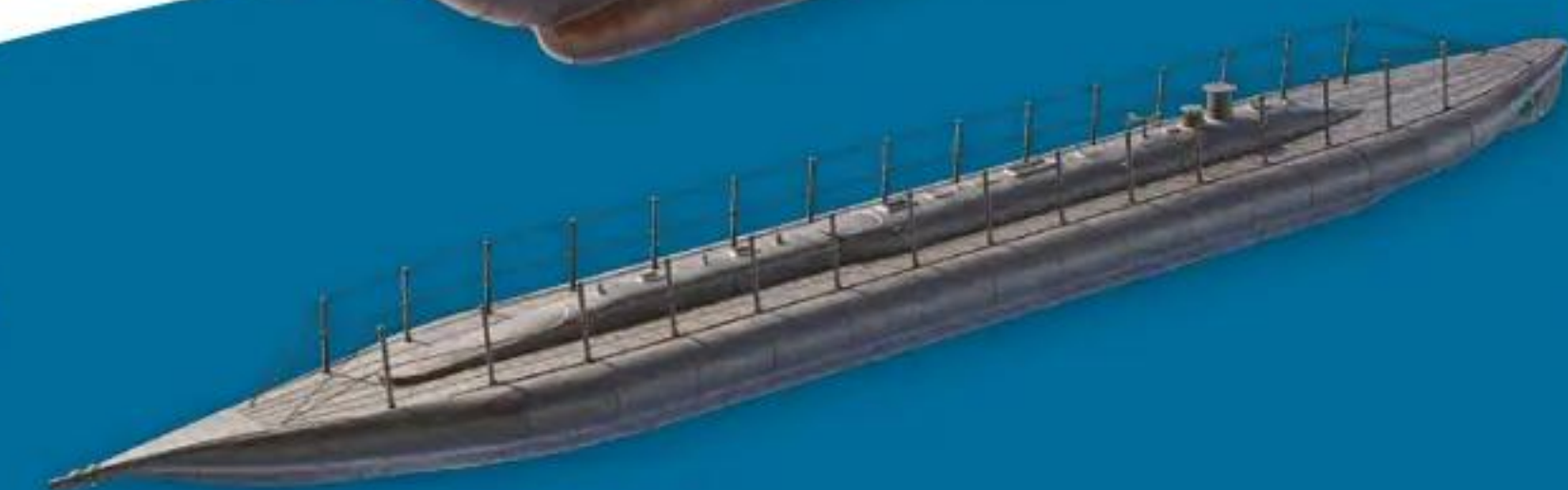
CREW: 3

PLONGEUR

Powered by engines running on compressed air, the Plongeur was the first submarine to not rely on human propulsion. It had a ram and torpedo, but engine problems meant it never passed the trial stage.

MAX SPEED:
7.2kph

RANGE:
1 hour



1863

MAX DEPTH:
10m

CREW: 12

USS HOLLAND

Irish engineer John Philip Holland was the first to use electric motors and an internal combustion engine to power an underwater vessel. His creation was purchased by the US Navy and influenced many further designs.

MAX SPEED:
9.3kph

RANGE:
5 hours



1900

MAX DEPTH:
23m

CREW: 6

1954

MAX DEPTH:
213m

CREW: 116



HMS Astute firing a cruise missile in 2011

TYPE A26 SUBMARINE

The Swedish Navy's new high-tech submarine that will be almost invisible

With technology advancing at speed, it will not be long before we find out whether the future of submarines is supersonic, unmanned or something else entirely. In fact, the latter is being explored by defence and security company Saab, and it is currently constructing two new super-stealthy Type A26 submarines for the Swedish Navy. With intelligence gathering and surveillance along coastlines becoming increasingly important, these

high-tech submarines will be able to operate in shallow waters and also feature Genuine HOlistic STealth (GHOST) technology, making them virtually silent and almost impossible to detect. Per Neilson, program manager for the A26, says, "It will be much quieter, the sensors will be more advanced – detecting and documenting everything that goes on in the sea – and there will be a number of new capabilities such as the multi-mission portal in the bow that allows for the hosting of divers

and small manned or unmanned vehicles. It will be a first-class intelligence-gathering platform." The A26 sub will be capable of diving to depths of 656 feet (200 metres) and carry a crew of around 26 sailors.

MODULAR DESIGN

A sectional hull means that the submarine can be easily customised and upgraded, making it more cost-effective in the long term.

CLEVER COATING

The hull is coated in a material that absorbs noise and makes the submarine difficult to detect using infrared cameras.

ENDURANCE

Next-generation, air-independent engines burn liquid oxygen and diesel fuel and allow the submarine to stay fully submerged for several weeks undetected.

SILENT OPERATION

Rubber mountings minimise noise from the engines and other operating machines as well as help to absorb shocks from impacts.

UNIQUE SHAPE

The hull design helps to reduce noise caused by the movement of water around the submarine.

The A26 will be able to withstand temperatures down to -2°C

MAGNETIC DETECTION

Sensors control the electric current flowing through the hull, cancelling out any distortions to the Earth's magnetic field that can reveal the boat's location.

RECONNAISSANCE

Sophisticated sensors allow for improved intelligence gathering, which is collected and analysed using the onboard combat-management system

MULTI-MISSION

The sub can be easily customised for different missions. For example, the bow can be used to launch and retrieve either divers or UUVs.

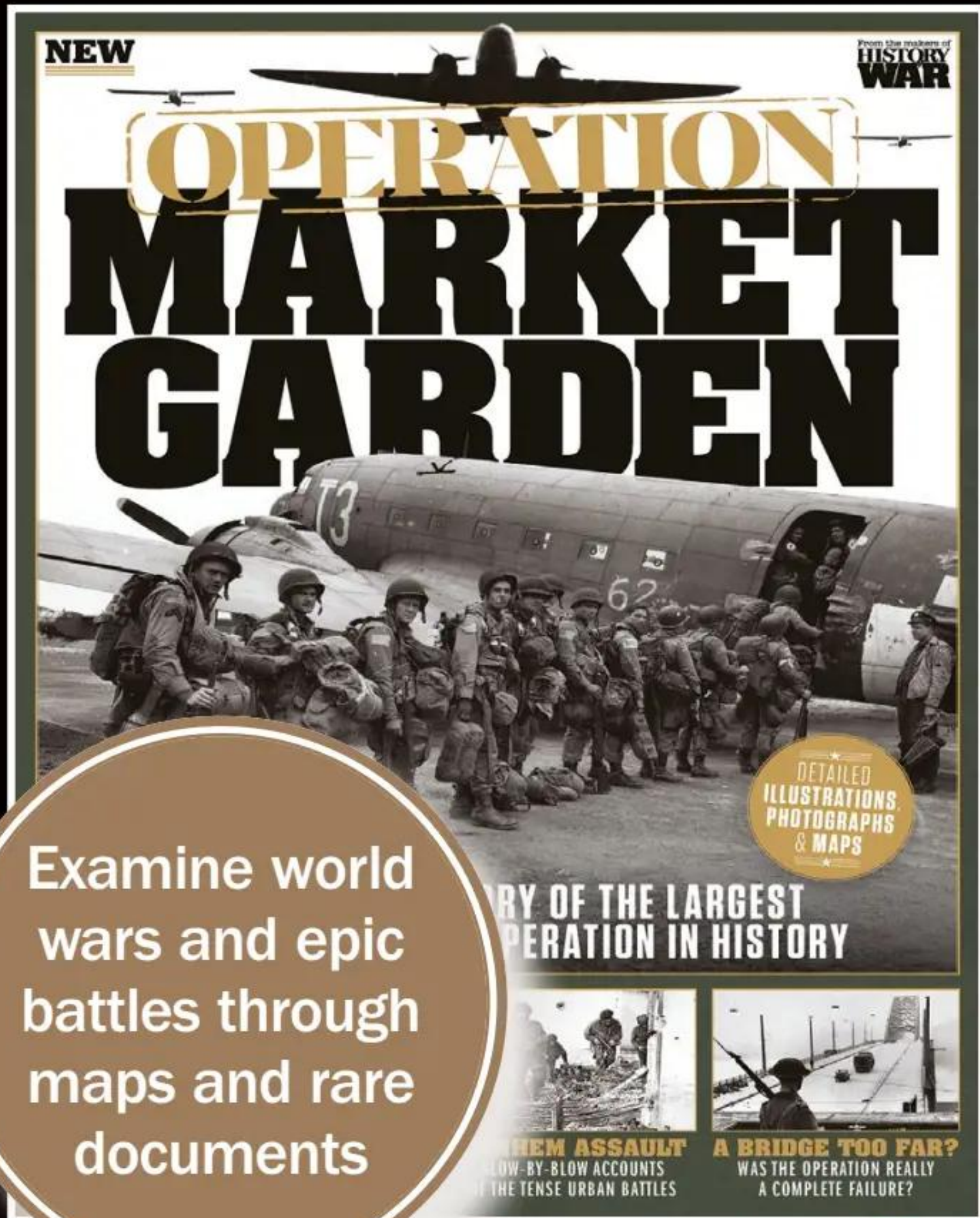
The A26 has a maximum speed of 12kts (22km/h) and can stay at sea for 45 days at a time

SHOCK RESISTANT

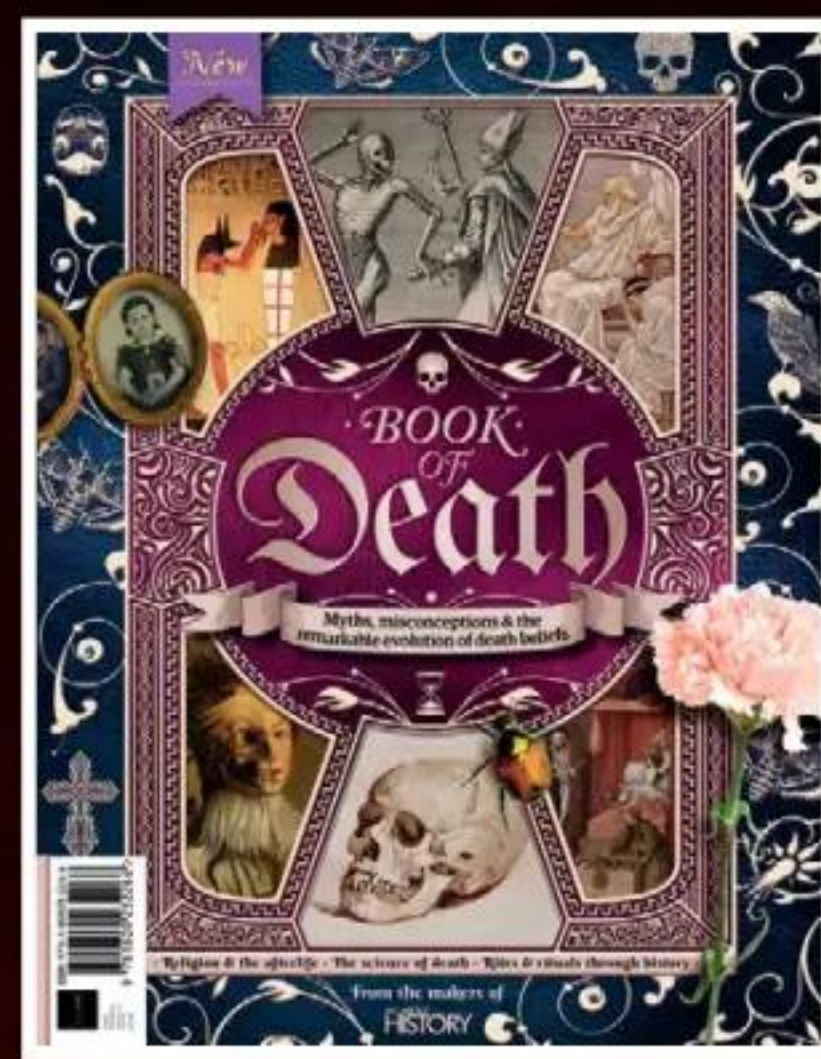
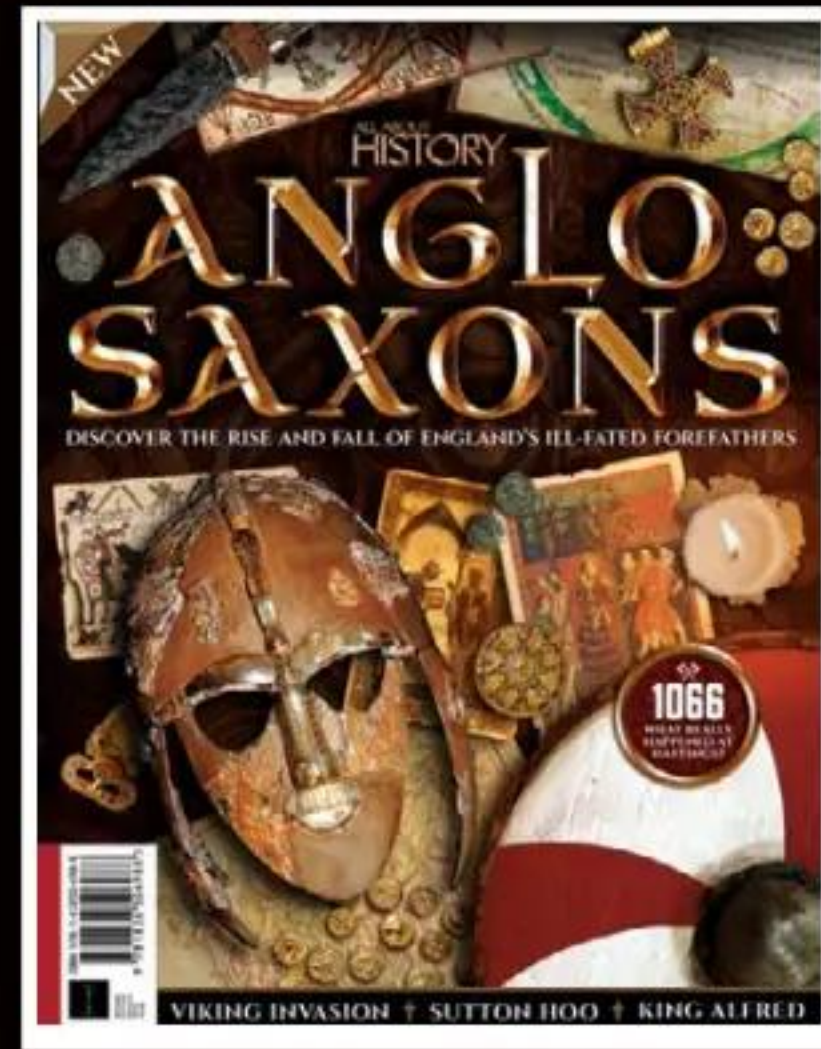
The submarine is constructed from special steels to ensure that it can withstand significant shocks from any underwater explosions.

HOW YOU CAN EXPLORE THE OCEAN

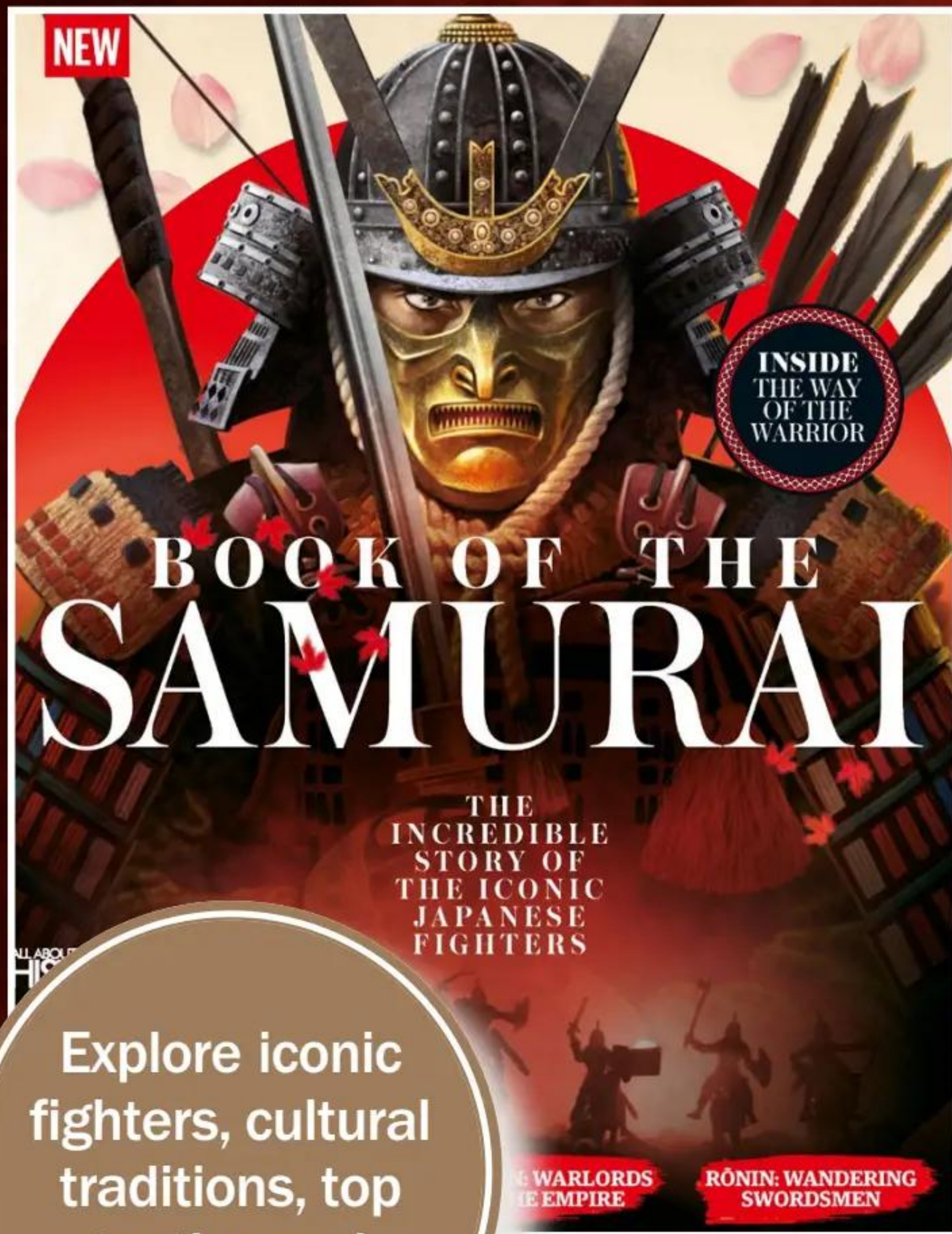
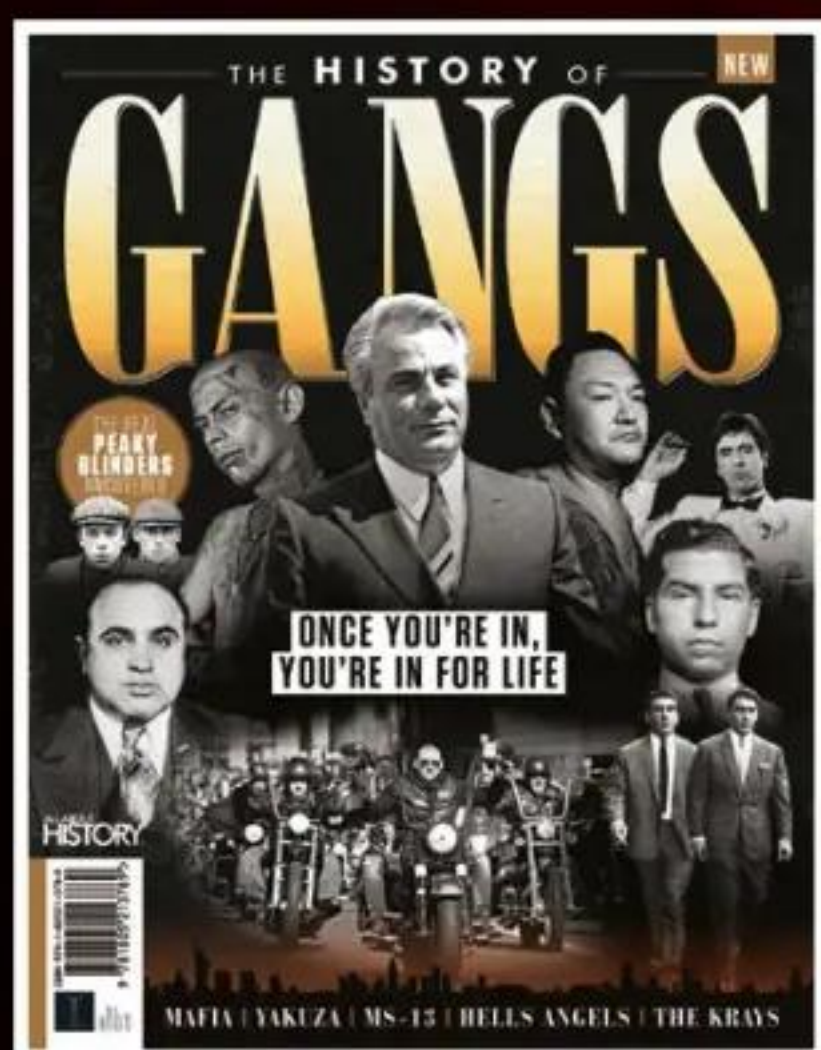
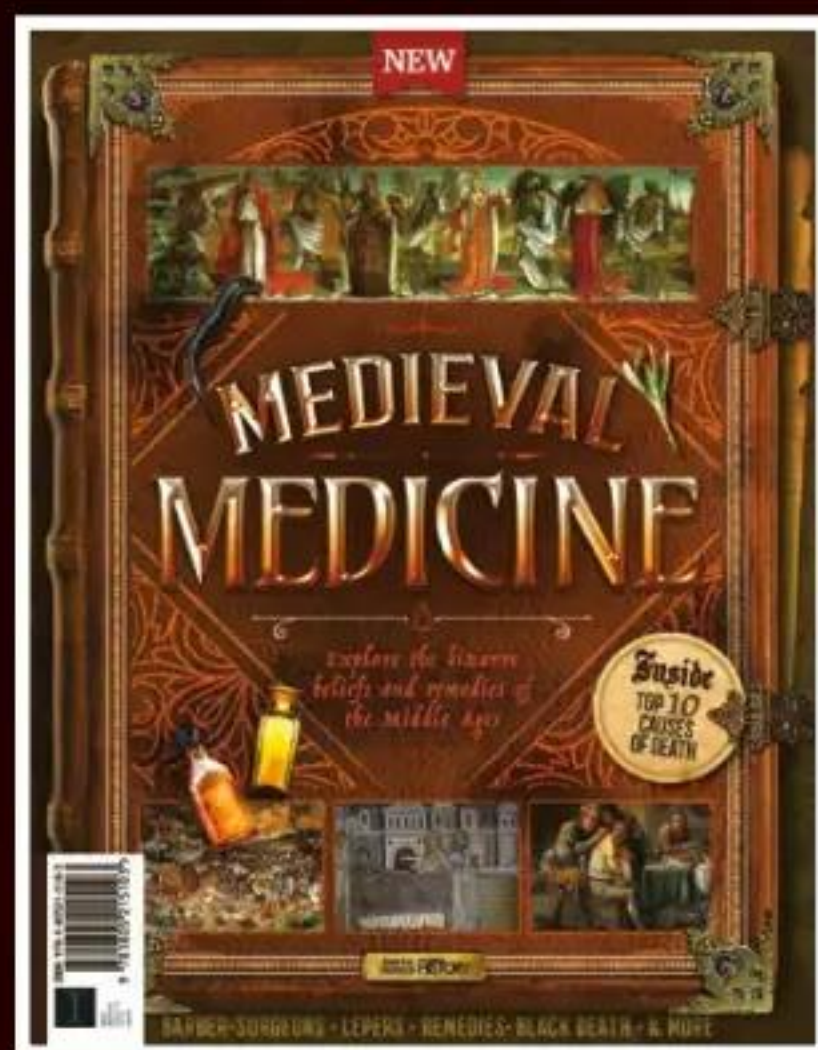
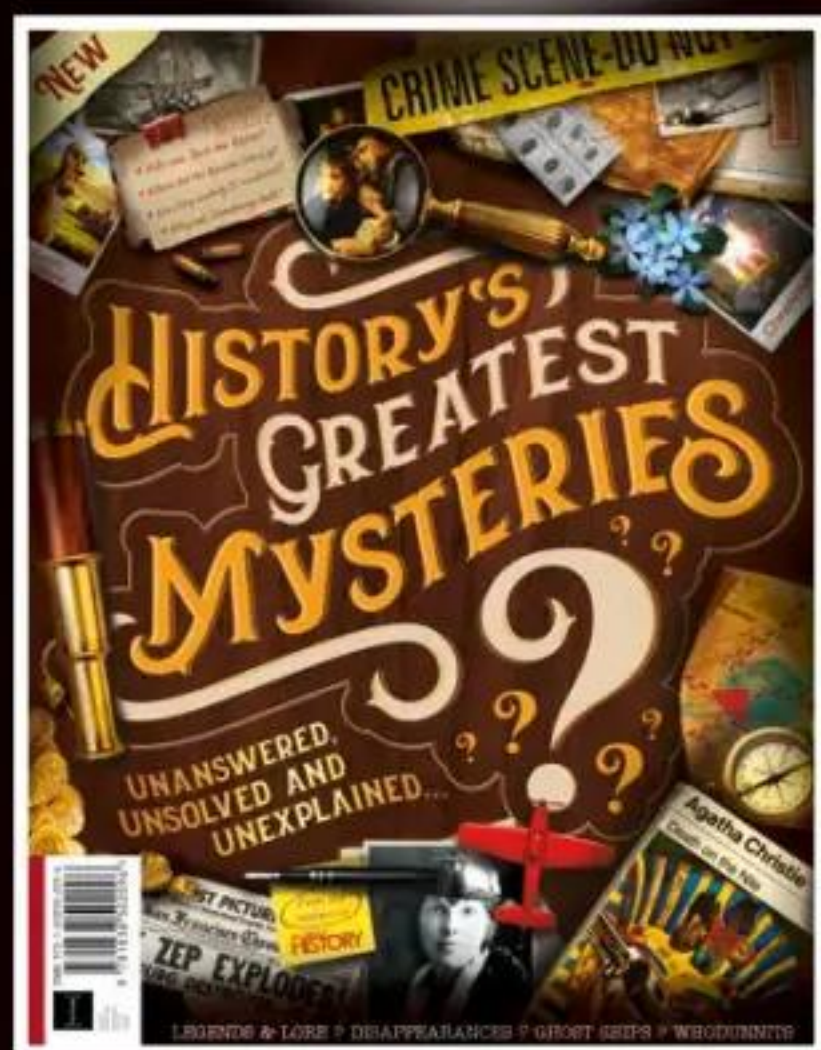
High-tech submarines aren't just reserved for the world's navies and scientists; DeepFlight has created a personal underwater craft that just about anyone can use to explore the oceans. The Super Falcon Mark II is an electric craft that can be operated with minimal training and dives to a maximum depth of 394ft (120m). It can carry two people, a pilot and a passenger, and is small enough to fit on a standard yacht, so you can take it for a dive wherever you are in the world. The submarine is safe to use around marine wildlife, and if you do encounter any trouble, whether it's shark-related or not, it will automatically return to the surface.



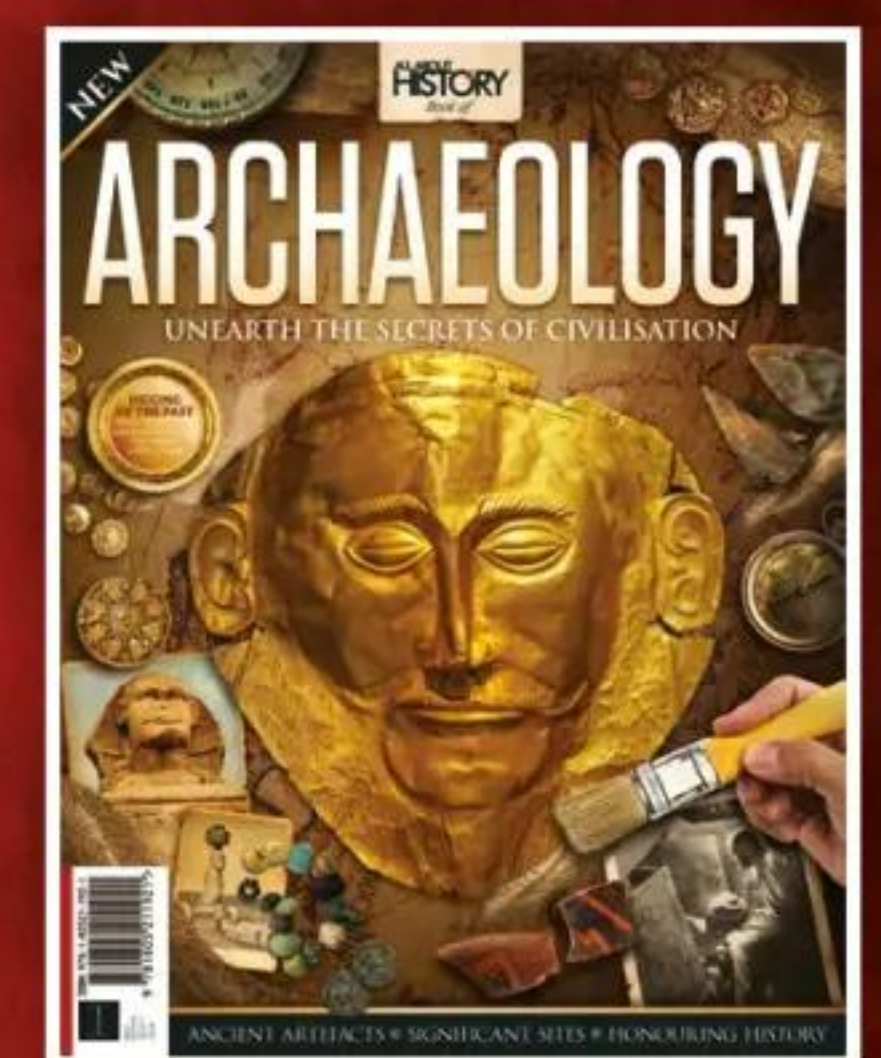
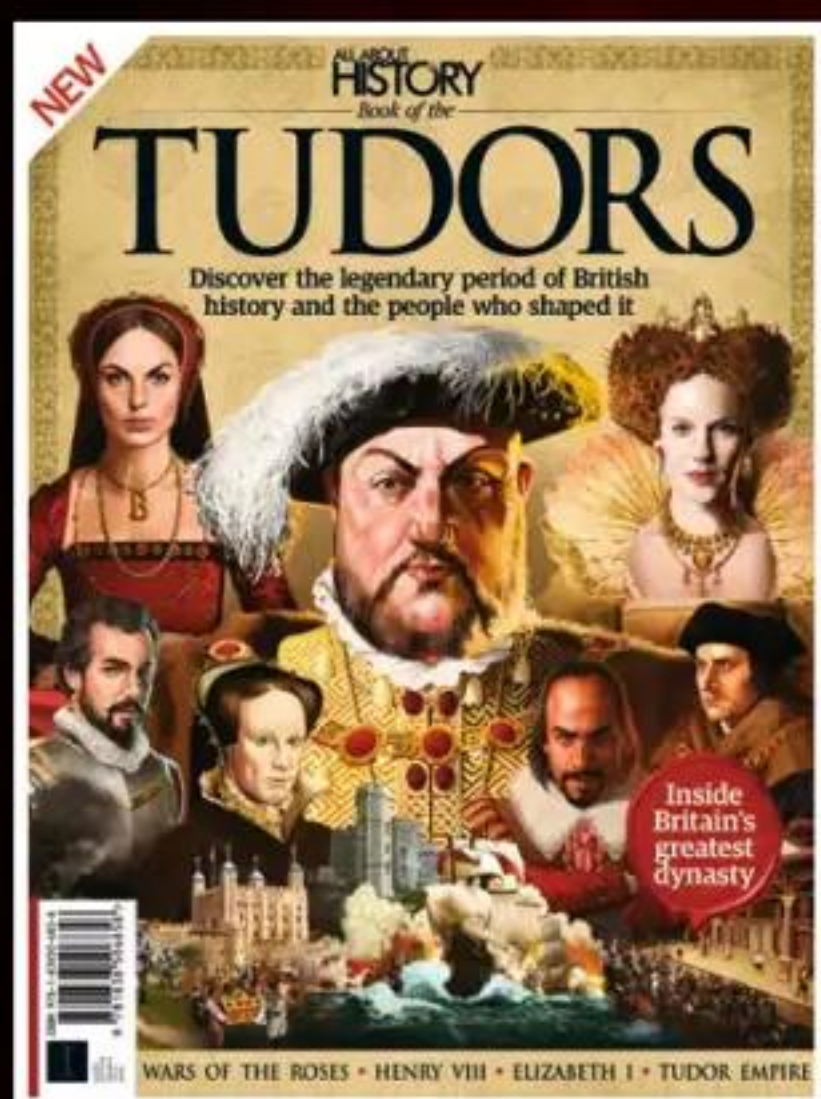
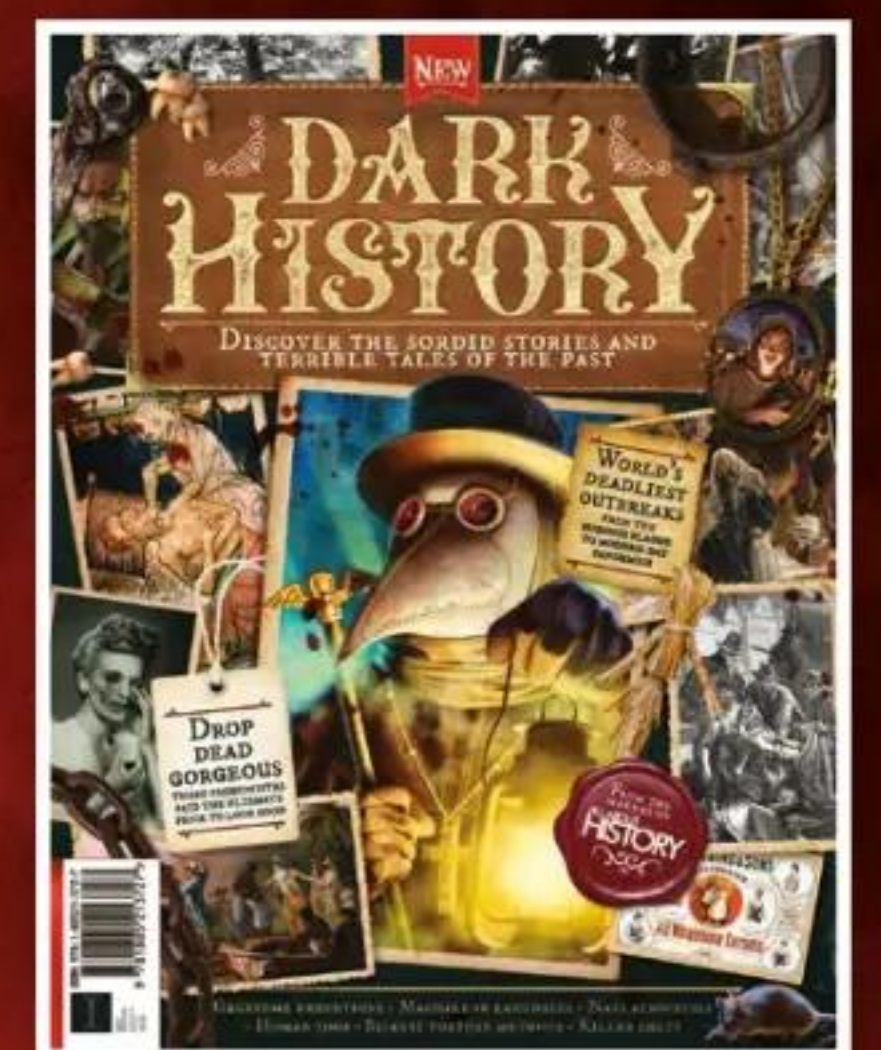
Examine world wars and epic battles through maps and rare documents



Step back in time and visit the most fascinating ancient civilisations



Explore iconic fighters, cultural traditions, top tactics and weapons



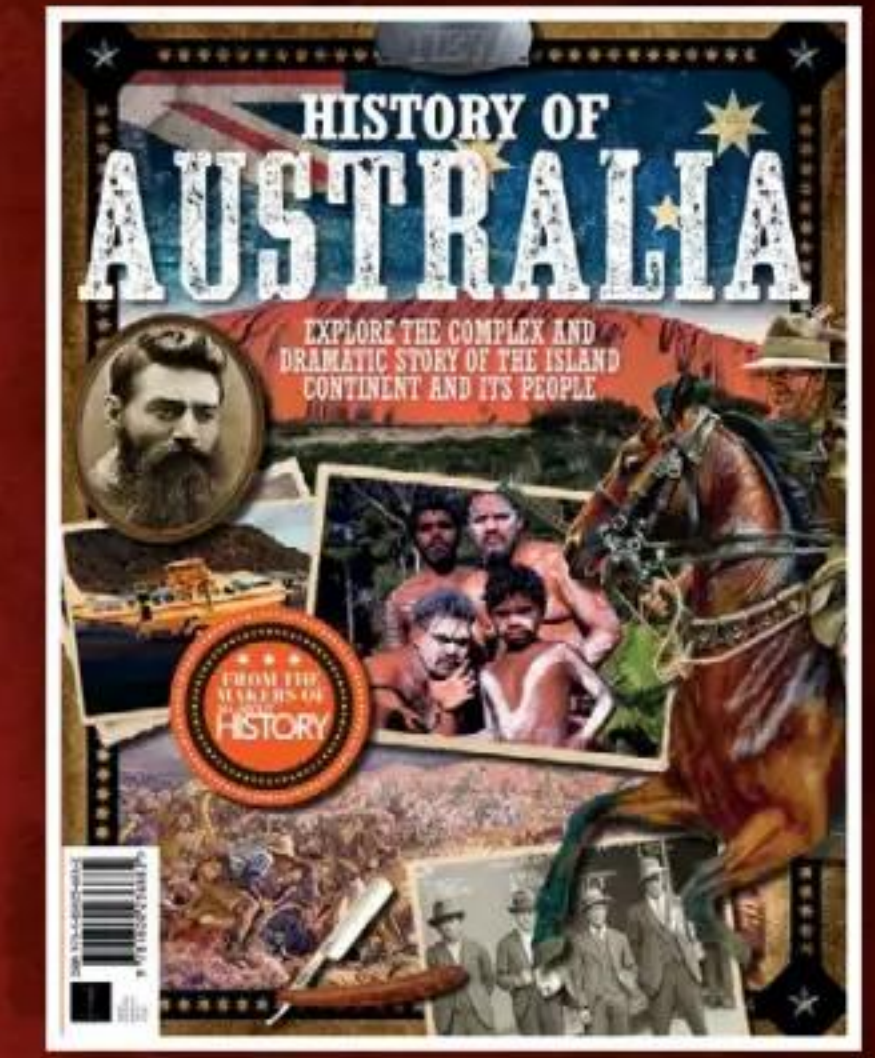
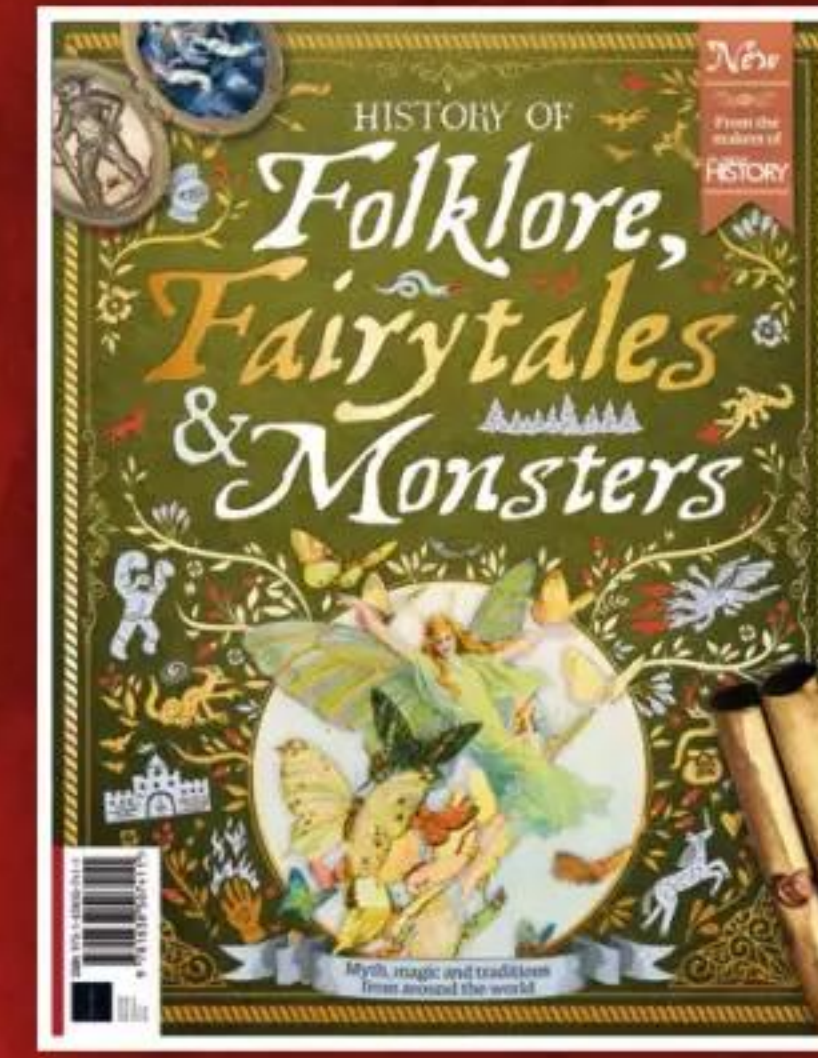
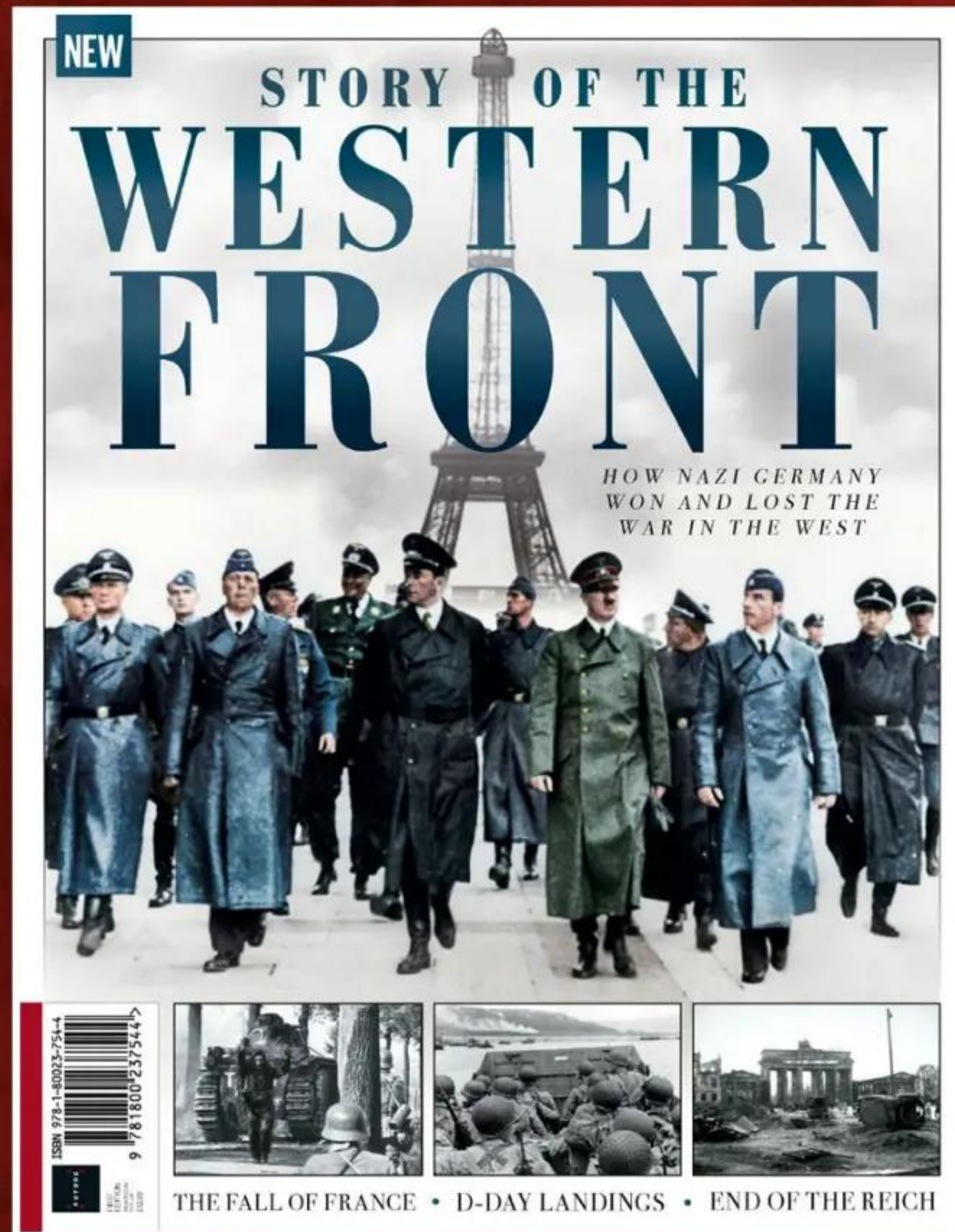
Get great savings when you buy direct from us



1000s of great titles, many not available anywhere else

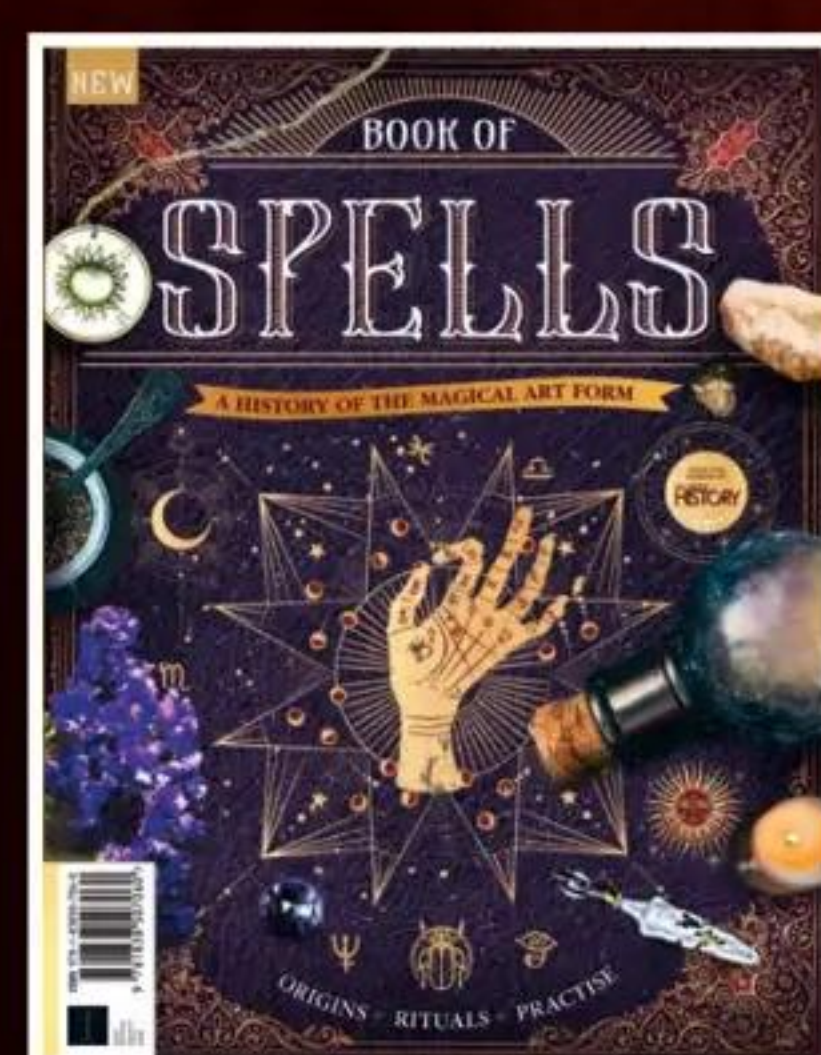
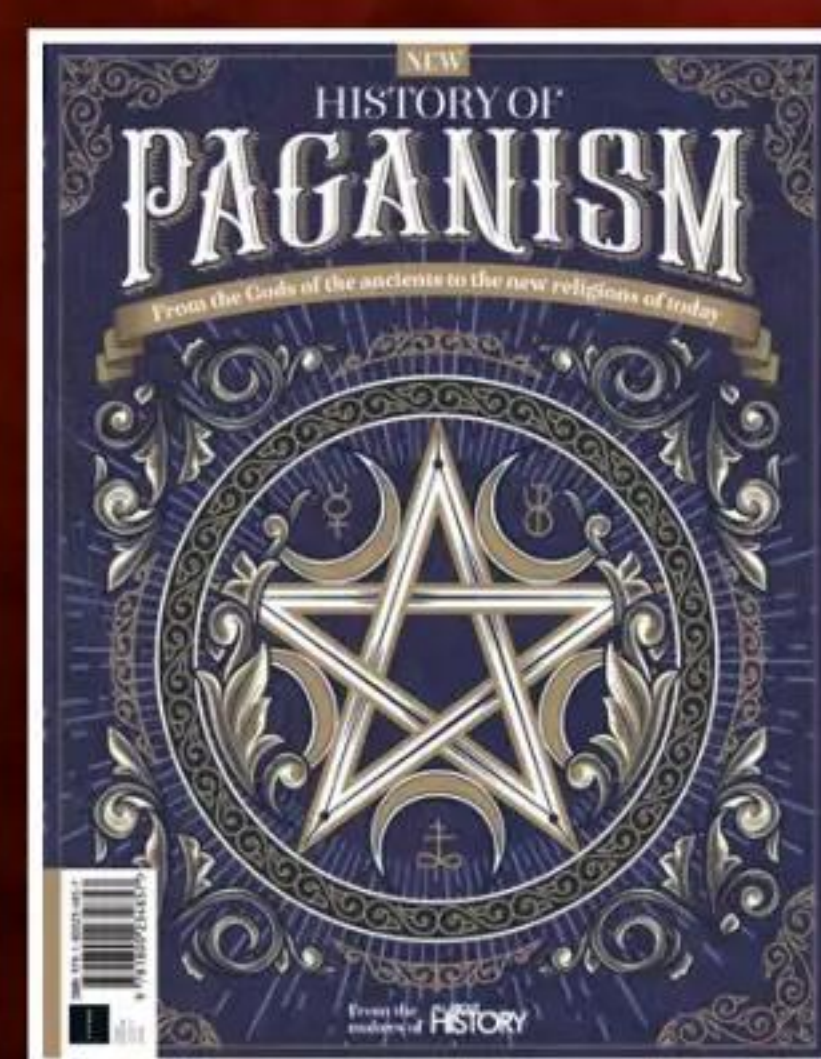


World-wide delivery and super-safe ordering



STEP BACK IN TIME WITH OUR HISTORY TITLES

Immerse yourself in a world of emperors, pioneers, conquerors and legends and discover the events that shaped humankind



Discover the answers to history's burning 'what if' questions



Follow us on Instagram  @futurebookazines



www.magazinesdirect.com/history
Magazines, back issues & bookazines.

MILITARY CUTAWAYS

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Military Cutaways Editorial

Senior Designer **Steve Dacombe**

Head of Art & Design **Greg Whitaker**

Editorial Director **Jon White**

Managing Director **Grainne McKenna**

History of War Editorial

Editor **Tim Williamson**

Designer **Curtis Fermor-Dunman**

Senior Art Editor **Duncan Crooks**

SVP Knowledge & Science **Joel Griffiths**

Contributors

Ben Biggs, Marc DeSantis, Scott Duffield, Stuart Hadaway, Ailsa Harvey,
Michael E Haskew, Craig Moore, John A. Taylor, Mark Wood,

Cover images

Illustrations by Alex Pang and Nicholas Forder
Images from Alamy and Getty Images

Images

All copyrights and trademarks are recognised and respected

Advertising

Media packs are available on request
Commercial Director **Clare Dove**

International

Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com
www.futurecontenthub.com

Circulation

Head of Newstrade **Tim Mathers**

Production

Head of Production **Mark Constance**
Production Project Manager **Matthew Eglinton**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Managers **Keely Miller, Nola Cokely,**
Vivienne Calvert, Fran Twentyman

Printed in the UK

Distributed by Marketforce – www.marketforce.co.uk
For enquiries, please email: mfcommunications@futurenet.com

GPSR EU RP (for authorities only)

eucomply OÜ Pärnu mnt 139b-14 11317, Tallinn, Estonia
hello@eucompliancepartner.com, +3375690241

History of War Military Cutaways First Edition (HWB7228)

© 2026 Future Publishing Limited

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this bookazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards.

All contents © 2026 Future Publishing Limited or published under licence. All rights reserved. No part of this magazine may be used, stored, transmitted or reproduced in any way without the prior written permission of the publisher. Future Publishing Limited (company number 2008885) is registered in England and Wales. Registered office: Quay House, The Ambury, Bath BA1 1UA. All information contained in this publication is for information only and is, as far as we are aware, correct at the time of going to press. Future cannot accept any responsibility for errors or inaccuracies in such information. You are advised to contact manufacturers and retailers directly with regard to the price of products/services referred to in this publication. Apps and websites mentioned in this publication are not under our control. We are not responsible for their contents or any other changes or updates to them. This magazine is fully independent and not affiliated in any way with the companies mentioned herein.



Future plc is a public
company quoted on the
London Stock Exchange
(symbol: FUTR)
www.futureplc.com

Chief Executive Officer **Kevin Li Ying**
Non-Executive Chairman **Mark Brooker**
Chief Financial Officer **Sharjeel Suleman**

Tel +44 (0)1225 442 244

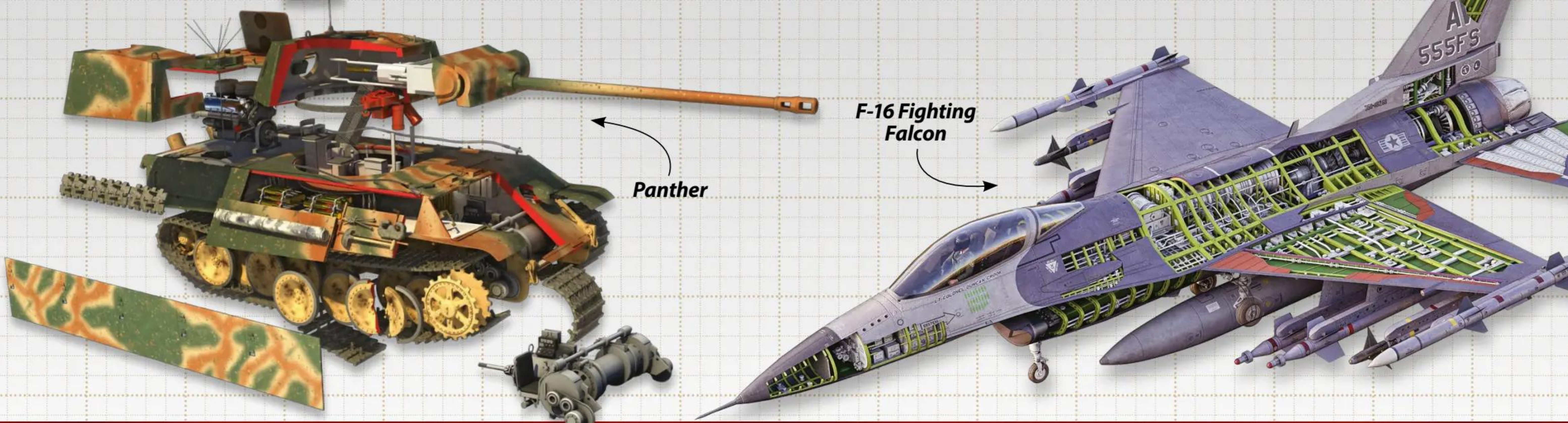
Part of the

HISTORY of WAR

bookazine series™

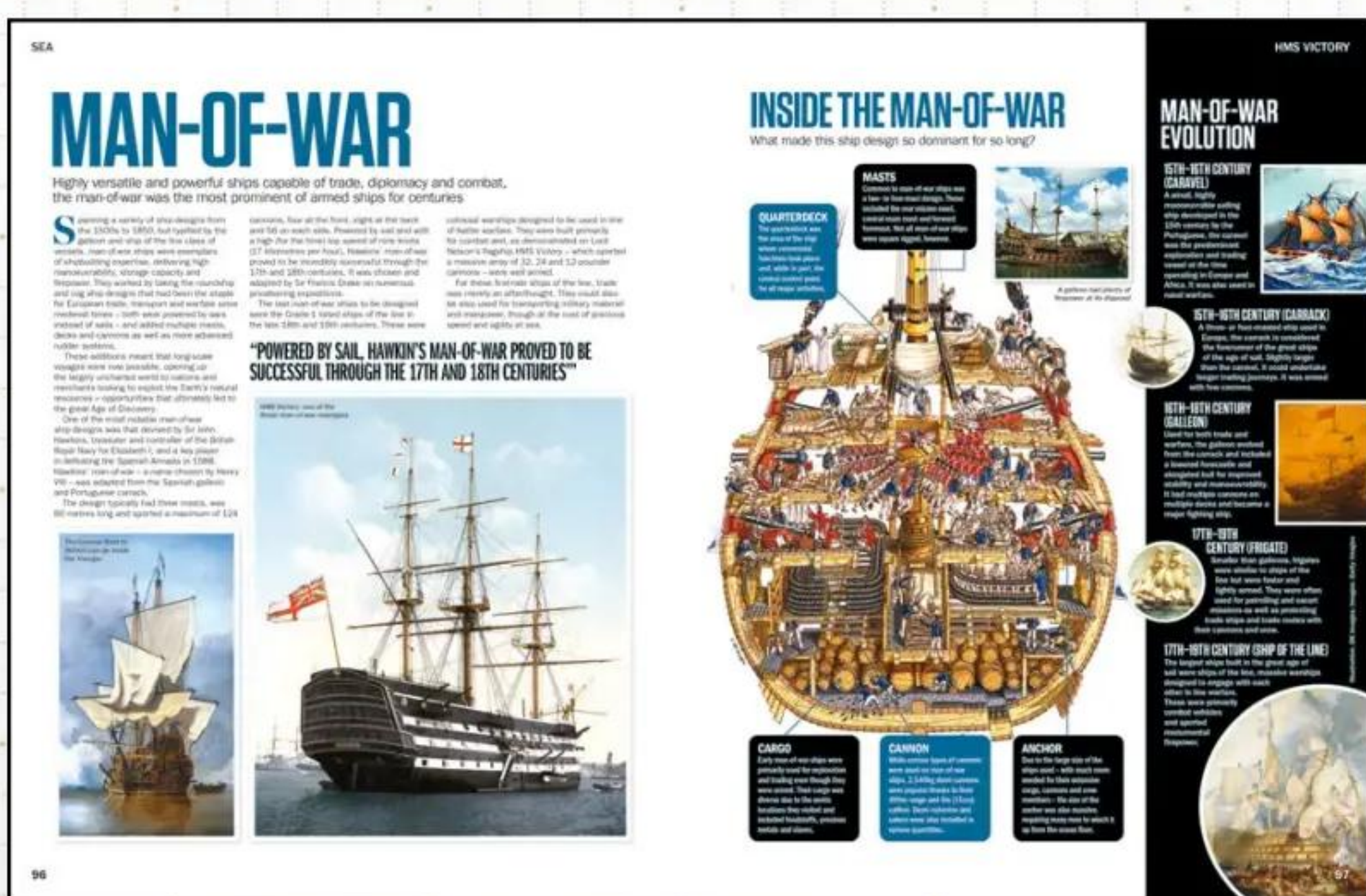






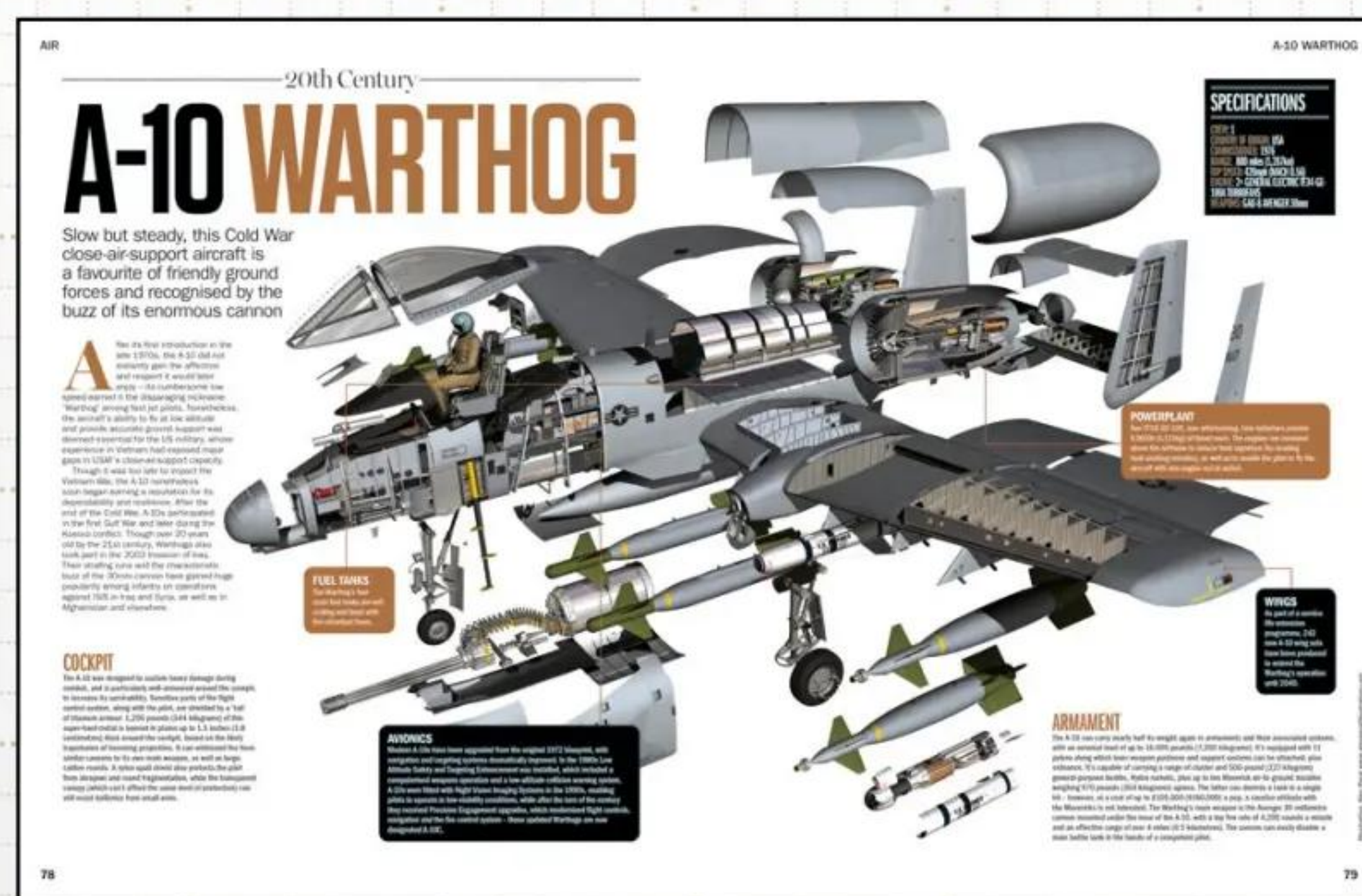
MILITARY CUTAWAYS

★ INSIDE THE ENGINEERING OF HISTORY'S GREATEST TANKS, FIGHTER PLANES, WARSHIPS & MORE ★



ANCIENT TO AGE OF SAIL

From Roman warships to the US carrier fleet – discover the vessels that ruled the waves



ICONS OF THE SKIES

Inside the cockpit of a First World War fighter, nuclear bomber, Cold War spy plane and more



ARMoured BEASTS

Genius design features and unstoppable firepower behind history's greatest battle tanks



MODERN MILITARY TECH

How 21st Century war machines are adapting to reshape the battlefields of the future